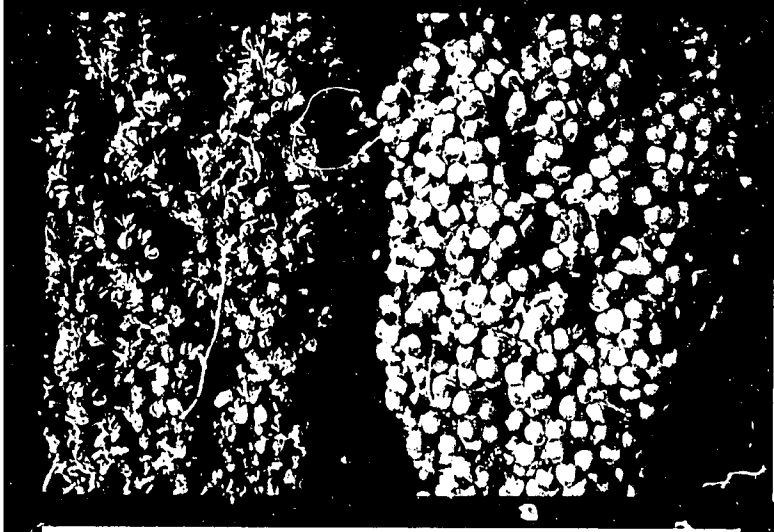
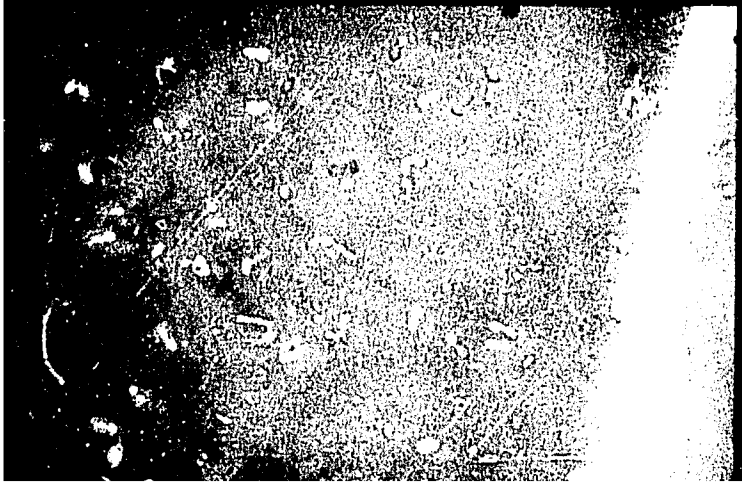
EXECUTIVE SUMMARY

INTSORMIL



# Annual Report 1993

## SORGHUM/MILLET COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)



***Fighting Hunger with Research ... a team effort***

Funding support through the Agency for International Development

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**Cover Photographs**
**(top to bottom)**

1. Sorghum line exhibiting "stay green" character for drought tolerance on right and susceptible line on left. Charcoal rot resistance is associated with the "stay green" characteristic. (Photo courtesy of Dr. Darrell Rosenow)

2. Example of infested sorghum head by panicle feeding bugs on left and uninfested sorghum head on right at Samanko Research Station, Bamako, Mali. (Photo courtesy of Dr. George Teetes)

3. Dr. El Hilu Omer, Agriculture Research Corporation (ARC), Sudan, demonstrating inoculation technique on pearl millet to Mr. Issoufou Kolo, INRAN/Niger and Dr. Joseph Werder, former plant pathologist, ICRISAT Sahelian Center in Niger. (Photo courtesy of Dr. Richard Frederiksen)

4. Agar gel *Striga* seed germination assay of Sorghum line N13. N13 is a high *Striga* seed germination stimulant producer. (Photo courtesy of Dr. Larry Butler)

PD ABJ-463

# INTSORMIL

# Annual Report 1993

**Fighting Hunger with Research . . . A Team Effort**

# Executive Summary

**Grain Sorghum/Pearl Millet Collaborative Research Support Program (CRSP)**

**The Sorghum/Millet Collaborative Research Support Program (CRSP) is an initiative of the Agency for International Development, Grant No. DAN-1254-G-00-0021-00, Title XII and the Board for International Food and Agricultural Development and Economic Cooperation (BIFADEC), the participating U.S. Universities and other collaborating institutions.**

**INTSORMIL Publication 94-5**

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**A Research Development Program of the Agency for International Development, the Board for International Food and Agricultural Development and Economic Cooperation (BIFADEC), Participating Land-Grant Universities, Host Country Research Agencies and Private Donors**

**INTSORMIL INSTITUTIONS**

**Kansas State University**
**Mississippi State University**
**University of Nebraska**
**Purdue University**
**Texas A&M University**

INTSORMIL Institutions are affirmative action/equal opportunity institutions.

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# Introduction and Program Overview

The INTSORMIL program, initiated in 1979, is one of ten Collaborative Research Support Programs (CRSPs) established through USAID core funding to respond to the Title XII legislation mandate to"... improve the participation of these (the agriculturally related) universities in the United States' governmental efforts internationally to apply agricultural sciences more effectively to increasing world food production and provide... support to the application of science to solving developing countries' food and nutrition problems". The INTSORMIL program was designed to respond to the intent of the Title XII legislation by focusing on grain sorghum and pearl millet related issues in strategically selected regions of the world.

Sorghum and millet are important world foods crops in moisture stressed regions of the world. They are staple foods for millions in Africa which, in their area of adaptation, cannot be substituted by other cereals. Sorghum is also a major feed grain in the U.S.

In working with selected host countries where sorghum and millet are important crops, INTSORMIL has mobilized the institutional and technical expertise of eight land-grant universities to focus on the special constraints of sorghum and millet production, processing, utilization, and marketing in the collaborating host countries. The universities which are still active in the INTSORMIL CRSP are Kansas State University, Mississippi State University, University of Nebraska, Purdue University, and Texas A&M University. The prime sites actively collaborating with INTSORMIL are Botswana, Colombia, Honduras, Mali, Niger and Sudan. Several other countries such as Senegal, Burkina Faso, Egypt, Kenya, Zimbabwe and El Salvador are also collaborating at a lower level.

The primary approach for INTSORMIL to reach its goal is to foster and cultivate the collaborative research mode involving the partnership of U.S. and host country scientists. They develop and transfer appropriate scientific technologies and strategies for alleviating the dominant sorghum and millet production and utilization constraints of the participating host countries and the U.S. Building and strengthening the manpower and the institutional capacities of the host countries for implementing effective collaborative research programs continues to be an important and necessary part of the INTSORMIL CRSP. INTSORMIL is committed to increasing production while maintaining and enhancing the natural resource base of sorghum and millet production both in the host countries and the U.S.

INTSORMIL currently provides technical backstopping, conducts collaborative research, trains national staff and students, and contributes operational support to National Agricultural Research Systems (NARS) grain sorghum and pearl millet programs. The success of INTSORMIL can be attributed to five unique features.

- INTSORMIL capitalizes on over 90% of U.S. Universities grain sorghum and pearl millet research capacity where most basic and strategic research is conducted. This allows the unique opportunity to support and complement applied field work conducted at NARS sites by adding an otherwise unknown dimension to the research.

- INTSORMIL is an integrated, interdisciplinary organization encompassing breeding, agronomy, physiology, insect and disease management, food quality, and economics.

- INTSORMIL enhances the capacity of NARS to solve country and region-specific problems through collaborative research, thus increasing NARS technical and institutional productivity.

- INTSORMIL activities are constraint and NARS driven: identification and alleviation of priority production constraints are achieved in concert with NARS.

- The INTSORMIL strategy focuses on five technical thrusts, each aimed at increasing productivity and improving sustainability:

  * Germplasm Enhancement—the development of resource efficient cultivars.

  * Sustainable Production Systems—the establishment of environmentally safe and financially profitable production systems.

  * Sustainable Plant Protection Systems—the development of environmentally sound and economical pest control systems.

  * Crop Utilization and Marketing —the development of shelf stable processed foods with good marketing potential as well as improving traditional food processing systems.

  * National Sorghum and Millet Research Program Enhancement —short and long term training for NARS staff, equipment procurement, and overall NARS operations support.

**Administration and Management**

The University of Nebraska (UNL) is the Management Entity (ME) for the Sorghum/Millet CRSP and is the primary grantee of USAID. UNL subgrants are made to the participating U.S. Universities for the research projects between individual U.S. scientists and their host country counterparts. Country project funds, managed by the ME and U.S. participating institutions, flow to the country program in support of the research activities at the host country level. The Board of Directors (BOD) of the CRSP serves as the top management/policy body for the CRSP. The Technical Committee (TC), Ecogeographic Zone Council (EZC), External Evaluation Panel (EEP) and USAID. personnel advise and guide the ME and the Board in areas of policy, technical aspects, collaborating host country coordination, budget management, and review.

Several major decisions and accomplishments were made by the ME, BOD, TC and EZC during the past year.

- INTSORMIL's Strategic Plan for the next decade was developed. In connection with the preparation of the Strategic Plan, Brhane Gebrekidan, Acting Associate INTSORMIL Program Director, visited all INTSORMIL host country (except Colombia) and domestic institutions whose inputs were incorporated into the Strategic Plan Document. Subsequently two documents were prepared:

  * INTSORMIL CRSP: A Strategic Plan for the Next Decade

  * Status Reports on Domestic and Host Country Institutions

- The INTSORMIL External Evaluation Panel (EEP) completed its review of the host country sites, Botswana (March 6-10, 1993), Honduras (November 30-December 4, 1992), Mali (October 11-16, 1993) and Niger (October 16-23, 1993). Sudan and Colombia were not reviewed because of USAID travel restrictions to those countries. The Program Director traveled with the EEP to facilitate the site reviews.

  All the domestic sites (Texas, Mississippi, Nebraska, Kansas, and Purdue) were also reviewed during the year. The ME office was kept busy throughout the year organizing these extensive reviews of overseas and domestic sites.

- The major publications organized and published by the ME office during the year included:

  * INTSORMIL: Fighting Hunger with Research... MAKING HEADWAY

  * INTSORMIL Annual Report 1992, INTSORMIL Publication No. 93-2.

  * Proceedings of the Workshop on Social Science Research and the CRSPs (INTSORMIL Publication No. 93-3).

  * INTSORMIL Annual Report 1992, Executive Summary (INTSORMIL Publication No. 93-4).

- The INTSORMIL BOD approved the inclusion of host country representatives on both the TC and EZC.

- The INTSORMIL BOD approved the annual budget which includes a 7.8% reduction in funds.

- The Program Director, at the invitation of the Africa Bureau, represented the CRSP Council at the Africa Bureau sponsored workshop on "Agricultural Technology Development and Transfer Collaborators Workshop".

- The Program Director travelled to El Salvador and Honduras to pursue opportunities for a potential training contract with CENTA in El Salvador under a World Bank loan project and to finalize arrangements for the termination of INTSORMIL's resident scientist posting in Honduras.

**Training**

Training of host country scientists contributes to the capability of each host country research program to stay abreast of environmental and ecological changes which alter the balance of sustainable production systems. The strengthening of host country research institutions contributes to their capability to predict and be prepared to combat environmental and ecological changes which affect sorghum and millet. A well balanced institution will have to be prepared to prioritize and blend its operational efforts to accomplish the task of conserving and efficiently utilizing its natural resources.

Since its initiation, INTSORMIL trained a total of 739 students of which 517 were from foreign countries and the remaining from the U.S. Out of the total number of foreign students trained, 284 were from Africa. Of the trained African students, 14% were female. About 83% of the total number of trainees obtained M.S. or Ph.D. degrees while the remaining 17% received Post Doc, B.S., or short term visiting scientist training. The distribution of the INTSORMIL trainees in the past fifteen years by gender and geographic origin is given below.

**Distribution of trainees by country of origin and gender**

| Origin | Females | Males | Total | % Females |
|---|---|---|---|---|
| U.S. | 79 | 143 | 222 | 36% |
| Foreign | 103 | 414 | 517 | 20% |
| Africa | 39 | 245 | 284 | 14% |
| Others | 64 | 169 | 233 | 27% |
| Total | 182 | 557 | 739 | 25% |

The majority of the trainees over the past fifteen years have returned to their home countries and are serving there in various capacities. Comprehensive data on the current jobs and assignments of all former INTSORMIL trainees are not available. Many hold responsible administrative and research positions in the NARS. These former trainees are real assets in promoting and strengthening collaborative research in the host countries.

**Benefits to Host Countries**

The lasting benefits and advantages of the collaborative research philosophy initiated and pursued in this CRSP are its contributions to cementing a long term relationship between the U.S. and host country scientists and institutions involved.

Germplasm exchange, movement of seeds in both directions of the U.S. and host countries, has involved populations, cultivars, and lines carrying resistances to pests, diseases, *Striga*, drought, and soil acidity as well as elite materials which could be used as cultivars per se or used as parents in breeding programs. INTSORMIL funds have been made available to the collaborators in the NARS for essential research operation expenses, including labor and materials, and equipment. A wide range of equipment has been provided to the NARS scientists for implementing collaborative INTSORMIL projects.

Improved varieties and hybrids have been developed for production by farmers in different INTSORMIL countries. In Sudan, two high yielding sorghum varieties have been developed and released through ARC/INTSORMIL collaboration, Ingaz (=M90393 = Salvation Government) and Feterita Wad Ahmad (=Cr35:18). Ingaz is grown under irrigation in about 60,000 ha in the Gezira, and Feterita Wad Ahmad is targeted both for rainfed and irrigated conditions and is under large scale seed increase. A *Striga* resistant variety, SRN-39, has been identified as promising and released for production. In one area alone about 1200 ha of SRN-39 have been grown in 1992. The hybrid sorghum success story in Sudan traces to ICRISAT/INTSORMIL/ARC collaboration in which they developed, produced seed, and popularized the first hybrid sorghum, Hageen Dura-1 (=Tx623 x K1567), currently covering about 12% of the sorghum area in the Sudan Gezira Irrigation Scheme, the largest in the world under one management. The HD-1 success story has become famous and has been recounted in many circumstances.

In Niger, one sorghum hybrid (NAD-1 = Tx623 x MR732) has been sufficiently tested and introduced to farmers and policy makers through a number of strategically located large scale demonstration plots. Policy makers in Niger have been impressed and farmers have been excited with the potentials of NAD-1. Reliable mechanisms for large scale seed production of NAD-1 have yet to be worked out. Among the varieties tested and released in Niger are SRN-39 and SEPON-82.

In pearl millet, the cytoplasmic-genetic male sterile 79-2068A is used extensively as a seed parent of hybrids grown in Northwest India. These same lines are being used widely in breeding programs by ICRISAT and the Indian national program to develop improved hybrid seed parents.

In Honduras, three food type high yielding sorghum cultivars have been tested and released. These are Tortillero (=CS3541 Sel.), Catracho (=ATx623 x Tortillero), and Sureño [(=SC423 x CS3541)E35-1]-2-2. Sureño, in particular, has widespread acceptance by Honduran farmers because of its superior grain quality, high yield potential, disease resistance, and dual purpose use for both forage and grain.

In Colombia, two sorghum lines, Sorghica Real 40 and Sorghica Real 60, have been released as acid soil tolerant cultivars suitable for the immense South American Llanos and Cerrados which are rendered unproductive by acid soils and high aluminum (Al) saturation. These cultivars should open up the vast acid soil affected areas for sorghum production.

In crop protection, a wide range of sources of resistance for insects, diseases, and *Striga* have been identified and crossed with locally adapted germplasm. Among the best of these are Malisor 84-7 and SRN-39 for head bug and *Striga* resistance, respectively. An effective screening method for head bug resistance has been developed in Mali. A reliable germplasm screening technique for sorghum long smut has been developed in Sudan and extended to other INTSORMIL countries in west Africa.

In agronomy and soil/crop management, a major INTSORMIL impact has been in understanding the soil/cropping system genotype interactions. Research in Mali has shown that small nitrogen additions are beneficial and necessary to sustaining sorghum grain yields. This information has been compiled and is being used by extension personnel in their discussions with farmers. In Botswana, the benefits of single element fertilizer have been determined and demonstrated to farmers. Water harvesting technology has been evaluated and appropriate recommendations have been extended to farmers. Additions of nitrogen have improved water use efficiency of both pearl millet and grain sorghum.

In food technology, the major achievement has been the establishment of well equipped and functioning sorghum and millet food technology and quality laboratories as in Mali and Niger. In Sudan, the use of sorghum in composite flour (up to 50%) for wheat bread making has been investi-

gated and its commercial viability and acceptability has been established. The newly released cultivars such as HD-1, Ingaz and SRN-39 have been evaluated for their kisra quality properties and have been found suitable.

In socioeconomics, the impacts of technologies generated by INTSORMIL, especially that of HD-1, have been assessed. The internal rates of return to the HD-1 breeding without any further extension of the absolute area in HD-1 were 23 to 31% for low and high fertilization, respectively. With the present rate of diffusion, the investment on this research would pay approximately $1 million of annual benefits. INTSORMIL's socioeconomic research has also shown that in Honduras the internal rate of return to the development of two new sorghum cultivars, Sureño and Catracho, which are in diffusion, is estimated at 32% or, on annuity basis, $0.7 million annually for the next 30 years. Thus, the new sorghum cultivars in Honduras have benefitted small farmers dependent on small-acreage hillside farms.

**Benefits to the U.S.**

The economic benefits of INTSORMIL research to U.S. agriculture has been hundreds of millions of dollars. Economic gains to the U.S. from research on developing the greenbug resistant (biotype E) sorghum alone was estimated at $389 million under the 1989 farm program provisions. Also, the economic benefits of research on developing food type varieties/hybrids was estimated as $183 million net welfare gain to the U.S. A wide range of sorghum and millet germplasm with high yield potential, improved grain quality, and resistance to pests and diseases have been introduced from the host countries through this CRSP. These materials have continuing potentials for generating millions of dollars of benefit to agriculture in the U.S. As a result of their involvement in this CRSP, a pool of U.S. scientists that is familiar with the global circumstances of sorghum and millet improvement, production, protection, utilization, and economics has been realized.

**Sustainable Plant Protection Systems**

Numerous pathotypes of sorghum downy mildew (SDM) from various regions of the world have been defined and sources of resistance to these pathotypes have been identified. Recently, host genes for resistance have been mapped and specific probes for identifying the presence of the SDM pathogen or several other downy mildew fungi have been described.

INTSORMIL PIs developed an International Anthracnose Virulence Nursery which is used to monitor the pathogen. This nursery is now managed in cooperation with ICRISAT. The system of networking includes the growing of several uniform nurseries in locations where sorghum/millet diseases are important such as the International Sorghum Anthracnose Virulence Nursery which is grown where anthracnose is endemic. Other nurseries include a uniform nursery for head smut, sorghum downy mildew, sorghum viruses, and grain mold. Growing of these nurseries permits a quick evaluation of pathotype differences among locations and the severity of the problem. INTSORMIL also evaluates and distributes elite sorghums in nurseries for evaluation of the multiple resistance of sorghum. These are international nurseries and represent a means of distributing elite germplasm from different breeding programs in INTSORMIL.

The identification of the "F" mating population as the major cause of *Fusarium* stalk rot in the U.S. and the provision of appropriate strains for breeders has greatly increased the screening reliability for resistance to this disease. Within a biological species there is limited genetic variability in material from the United States and somewhat more variability in material examined from LDCs. INTSORMIL PIs have developed VCG (Vegetative Compatibility Group) technology and protocols so that LDC scientists can make estimates of the genetic variability within their pathogen populations.

A collection of approximately 6,000 cultures of *Fusarium* based on world wide collections is maintained at Kansas State University. Many of these strains have been genetically characterized, and have known mycotoxin or pathogenicity profiles. Pharmaceutical companies are screening this unique collection for novel secondary metabolites for therapeutic value. This collection complements other major collections of *Fusarium* that are maintained in Pennsylvania, Australia, Germany, and the Republic of South Africa.

INTSORMIL PIs have developed a dot immunobinding assay (DIA) to distinguish different bacterial pathogens of sorghum and millet. The test is easy to perform, inexpensive, requires limited equipment and chemicals, and was designed with LDC laboratory conditions in mind. It has been shown that the causal agent of bacterial leaf streak is seedborne and can remain viable in the seed for more than two years.

An extensive phytopathogenic bacterial culture collection of over 600 species has been established in the laboratory at Kansas State University. This is the most comprehensive collection of plant pathogenic bacteria affecting grain sorghum and pearl millet in the world.

Insects cause more damage than pathogens, but pathogens become more severe as insect abundance and damage increases. Pathogens can occur without insects, but diseases may be significantly more serious when insects are present. The severity of pathogen infection is increased when rains continue late into the season, that is, when sorghum matures during wet conditions.

International collaborative research programs with NARS and ICRISAT scientists have resulted in the development of sustainable insect management strategies and identification of sorghums resistant to sorghum midge, greenbug (biotypes C, E, and I), African sorghum head bugs,

sugarcane aphid, and yellow sugarcane aphid. Mechanisms and inheritance of resistance have been determined, and genes conferring resistance have been introgressed into elite parental lines that have been evaluated alone and in hybrid combinations. Levels of resistance have been quantified, and economic injury levels established for most of them.

Research at Texas A&M University has employed a holistic approach to identify, evaluate, and deploy sorghum midge, greenbug, and yellow sugarcane aphid resistant sorghums as a component of IPM, and develop and validate sorghum plant and sorghum midge dynamics computer models. Significant advances were made in developing the technology to allow farmers to manage these sorghum insect pests.

Significant advances have been made in biological control and these advances contribute to improved IPM of sorghum and millet, and to improved concepts for using biological control in annual crops. For aphids attacking sorghum in the U.S., predators were demonstrated as key natural enemies for effective biological control of these pests. In the U.S., phytoseiid predators have been demonstrated as an effective alternative to pesticides for control of spider mites, and parasites were shown to be effective on the American sugarcane borer attacking sorghum.

Since the initiation of INTSORMIL, cooperation between sorghum breeding and sorghum entomology projects has resulted in the registration and release of 65 sorghum midge-resistant A- and R-lines (Tx2754-Tx2781, Tx2801-Tx2815, Tx2869-Tx2890). For greenbug, 33 sorghum lines resistant to biotype C (Tx2567-Tx2568, Tx2734-Tx2752, TAM Bk41-44), and 11 lines resistant to biotype E (Tx2783, Tx2859-Tx2868) were registered and released. Of these releases, ATx2752 and RTx2737 were extensively used in commercial sorghum hybrids for resistance to biotype C, and RTx2783 and its derivatives were extensively used for commercial hybrids resistant to biotype E.

The impact of insect resistant germplasm in sorghum production of the U.S. has been dramatic. For example, insecticide use on sorghum in Texas was at an all-time high at the initiation of this CRSP. In 1978, nearly 60% of the sorghum acreage in Texas was treated with insecticide, while in 1990 only about 24% of the acreage was treated. The savings gained from not using insecticide were $6,000,000 per year, and this does not consider the ecological or environmental benefits, or benefits from reduction in insect pest resurgence or secondary pest outbreaks. During this project, the economic benefit to Texas farmers has been at least $90,000,000.

INTSORMIL PIs at Purdue and their collaborators identified sorgoleone, a group of chemically reactive oily quinones exuded from the root hairs of sorghum, as the first natural germination stimulant identified from a *Striga* host. Sorgoleone has other activities, including herbicidal and antibiotic, and is a powerful contact allergen. In the field, *Striga* germination is not controlled by sorgoleone but by a different set of compounds exuded by host roots. These compounds are more stable and more water soluble than sorgoleone.

The INTSORMIL PIs at Purdue consider each stage of the *Striga* life cycle separately. They characterize the host-parasite interaction at each stage, particularly the chemical signals exchanged. For each stage simple ways to detect ineffective interactions are sought. These screening methods are used to identify crop genotypes bearing the resistance conferring traits, and to map the traits on the sorghum genome.

INTSORMIL investigators in Niger did not find any significant interaction between N, P, K in *Striga* control. Nitrogen application did not reduce the amount of *Striga* infestation, but this may be explained by previous fertilizer trials in the plots. Phosphorous application reduced the number of *Striga* at Kollo and increased it at Bengou. Potassium had no effect on *Striga* at Kollo but increased it at Bengou.

**Sustainable Production Systems**

In the area of plant physiology, current water stress research is centered on preanthesis stress mechanisms (metabolic efficiency, heat shock protein development, etc.) and post anthesis stress research as it relates to improving seed size. Improving seed size capacity is probably a valuable preanthesis stress compensating factor. A workable preanthesis stress screening program based on yield component analyses to help identify the time of stress damages was developed. A stress resistant hybrid consumed only half the $0_2$ required to produce a gram of root dry matter as did a stress susceptible hybrid making the stress resistant hybrid twice as efficient in utilization of respiratory energy. It was shown that genotypes could be selected for tolerance of the photosynthetic mechanisms to stress. In this regard, heat tolerance of pearl millet was found to be higher than that of sorghums.

Research in the area of mineral stress, particularly nitrogen, has shown that certain genotypes cope with low soil nitrogen better than others by a rapid mobilization of that element to actively growing tissue which sustains whole plant photosynthesis and thus growth. Also, certain sorghum genotypes have higher photosynthesis rates at lower tissue nitrogen concentrations than others which allows continued growth at low nitrogen supply.

INTSORMIL research results have demonstrated 18 to 203% yield enhancement of pearl millet and grain sorghum yields by use of crop rotation with legumes, and a sizeable nitrogen equivalent contribution to cereals following legumes. Intercropping has shown land use efficiency increases over sole crops, and also to enhance yields of succeeding crops. Obviously legume production, no matter the system,

is important to producing optimal yield when nitrogen fertilizer is limiting and improved cultivars are available.

Foliar spraying of sorghums with abscisic acid (ABA) increased yields of some genotypes under drought stress, mainly due to increased seed numbers, while decreasing or having no effect on the yield of well watered plants. Seeds treated with ABA had increased germination, longer root growth, and better seedling tolerance to drought stress. The ABA treatment was more effective on stress susceptible genotypes.

**Germplasm Enhancement and Conservation**

INTSORMIL PIs have developed numerous germplasm lines resistant to biotype C and/or E greenbug which have been distributed to private seed companies for use in their breeding programs. Several lines have been extensively used directly in the production of hybrids and they include ATx2752, Tx2737, Tx2783, Tx2864, and Tx2862.

Germplasm resistant to sorghum midge, developed through INTSORMIL support, has served as the foundation for many similar breeding programs throughout the world. Lines used, or those that could be used, directly in sorghum hybrids include ATx2755, Tx2767, Tx2880, and Tx2882.

INTSORMIL PIs have cooperated in the release of three hundred fifty converted exotic sorghum lines. The releases were made in three groups: two hundred forty lines in 1986, fifty in 1992, and an additional sixty in 1992.

Results have consistently shown that grain yields at high and low fertility as well as yield responses to fertilizer are to some degree independent of one another. Therefore, it is incorrect to assume that selection of sorghums under adequate soil nutrient conditions will result in sorghums that perform well under nutrient stress. Sorghum performance at low nutrient levels, yield potential under good conditions and responsiveness to applied fertilizer appear to each be under separate genetic control.

The identification of Hageen Dura-1 in the Sudan was an impressive finding. The female ATx623 was used because of its wide adaptation and yield potential, as well as its drought resistance. A sister line ATx622 has been introduced in China and used in hybrids planted on tens of thousands ha.

Eight genes have been described which affect the food quality of sorghum grain; pericarp color, presence or absence of a pigmented testa, thickness of pericarp, nature of endosperm, and basic plant color. More than 14,500 sources of germplasm, inbred lines, and enhanced populations have been distributed to collaborators. These materials have been incorporated into national breeding programs, selected for release to farmers, and used in training programs.

One major dominant gene and one major recessive gene were found to control the ability to stay green under drought conditions. A consistent relationship has been shown between high nonstructural carbohydrates in the stem and charcoal rot resistance. Two-gene systems appear to control relative water content, osmotic potential, and heat tolerance. One INTSORMIL project, TAM-121, has developed and released 68 inbred parental stocks for use domestically and internationally since the INTSORMIL program was initiated. More than 10 countries are known to have released hybrids using materials developed in this project.

It is now known that genetic variability for tolerance to the tropical acid soil complex exists in the genus *Sorghum*. Tolerant varieties have been released and are producing economic grain yields for resource-poor farmers in marginal production areas using low-input technology. Information has been obtained concerning gene action and inheritance of tolerance to Al, Mn, and acid soils in general. Since tolerance to the acid soil complex appears to be dominant in sorghum, either tolerant pollinator or seed parent lines can be used to produce commercial cytoplasmic-genic hybrids in tropic or temperate zones. After screening nearly 6,000 sorghum genotypes, INTSORMIL PIs found that about 8% would tolerate 65% Al saturation and a few of these varieties would produce more than two tons of grain per hectare. Most of these highly tolerant genotypes were identified in the world collection as originating in acid soil areas in Nigeria, Uganda, and Kenya. The Colombian/ICA-INTSORMIL released Al-tolerant varieties, Sorghica Real 60 and Sorghica Real 40, have consistently produced high grain yields on acid soils in both cropping seasons during the year. Both cultivars have good yield stability in acid and fertile soils, and are photoperiod sensitive Caudatums.

The INTSORMIL/McKnight research group at Purdue, in collaboration with Pioneer Hybrid Seed Company, is the first to report the stable and heritable transformation of sorghum. This is a significant accomplishment which will allow new opportunities for sorghum improvement in the future. Transgenic sorghum plants have been obtained after microprojectile bombardment of immature embryos. The variety transformed is the drought resistant cultivar P-898012 which is well adapted to the African Sahel. This achievement will allow sorghum scientists to introduce new and useful genes into this important African sorghum variety, and could be the dawn of a new era for sorghum research.

A new drought tolerant sorghum hybrid designated NAD-1 has proven to be highly productive and well adapted in Niger. The grain quality is acceptable for local food preparations and the yields reported from demonstration plots in 1992 were approximately twice the yields of local varieties. Farmer interest has been very high since this is the first sorghum hybrid that has actually reached farmer fields and the head size and grain yield have been impressive to them. The 1992 trials, at over 100 farmer locations, was a critical test of the performance of this hybrid. It is important

now to develop a seed industry (either private or parastatal) in Niger that is adequate to produce and distribute hybrid sorghum seed.

In pearl millet, population improvement using mass-selection and $S_1$ progeny performance recurrent selection programs have resulted in improvements in tolerance to drought and low soil fertility, increased stand establishment capability, and excellent bird resistance in bristled populations. Good rates of progress have been made reducing lodging caused by poor root/soil attachment, nodal abscission layers, and charcoal stalk-rot. Improved stand establishment has been obtained by selecting rapidly emerging seedlings from planting depths of 100 mm in the greenhouse and 75 to 80 mm depths in the field. Selections surviving this type of screening emerge 0.5 to 2 days earlier than unselected lines when planted at normal depths and produce larger plants at 10 days after emergence.

Nearly all new accessions of millet entering the program are routinely screened for seedling tolerance to aphids. Approximately 75% of the accessions tested have moderate to high levels of resistance to greenbug, with most of the injured lines producing sufficient numbers of tolerant plants for effective selection.

Several superior seed parents have been obtained from the male-sterilization backcross program at Kansas. $F_1$ hybrids appear to have similar grain yield potentials when compared to sorghum hybrids of similar maturity. Three Kansas cytoplasmic-genetic male-sterile inbred lines and their maintainer lines have been used extensively for several years in the ICRISAT breeding program in India and have been released to public and private breeding programs in India for utilization in the production of hybrids. In the U.S., research continued on producing segregating populations for selection in West Africa, providing data on production of protogyny hybrids for use in low-resource agriculture and developing hybrid parent lines in the $A_4$ cytoplasmic male sterility system which has several major advantages over the $A_1$ system, and may also be useful for improving agriculture in developing countries.

### Crop Utilization and Marketing

INTSORMIL PIs in Indiana originally addressed the tannins as antinutritional factors. They developed methods, now widely used by others, for assaying and characterizing these materials. They also developed a simple method for detoxifying and improving the nutritional value of high tannin sorghum. They are elucidating the biochemical mechanisms by which tannins exert their antinutritional effects. They are also characterizing the role of tannins and related materials in resistance to birds, molds and leaf diseases. Methods for polyphenol analysis, purification and characterization have been widely adopted and used by nutritionists and ecologists studying tannins in other crops and range plants.

Sorghum digestibility in humans was shown by nutritionists to be low compared to other cereal grains, and from this project we now have a clear concept of why the storage proteins, or kafirins, are difficult to digest. Presently, a high molecular weight non-kafirin endosperm protein that inversely correlates to reduced digestibility is being evaluated as a possible means of increasing digestibility through breeding or genetic manipulation. INTSORMIL PIs have identified a sorghum line in the World Collection (IS 2319) which has a significantly reduced cross-linked kafirin fraction and shows very good digestibility results in rat feeding trials, whether cooked or uncooked. They believe this cross-linked kafirin is responsible for many of the digestibility problems in sorghum and are giving this activity a very high priority.

Processing sorghum in certain ways was found to effectively increase digestibility. A traditional fermented product, Sudanese *nasha*, and high temperature, low moisture extruded gruel made from decorticated sorghum were found to be highly digestible in children both in protein and energy. New processed foods from sorghum in Sudan were evaluated for nutritional quality and research was conducted that will improve quality and help efforts to commercialize *kisra*, the staple Sudanese fermented flat bread.

It was found that high amounts of kafirin decrease the gelatinization potential of the starch granules thereby making a thinner porridge. Porridge texture was found to be the most important attribute when different sorghum cultivars were evaluated using sensory panels in Niger. Laboratory tests for porridge quality were identified that best correlate to consumers in Niger. Grain hardness tests, which are important indicators of end-use quality, were evaluated and suitable methods that are rapid and simple were put in place.

Simple methods to evaluate milling and porridge quality of sorghum have been developed and used to produce new cultivars. For example in Mali, Malisor 84-7 was developed specifically for improved thick porridge quality. Its tan plant color and hard endosperm provides excellent quality grain which has been found to have resistance to head bugs.

The chemistry, composition, structure and nutritional value of sorghum kernels has been related to genes that control pericarp thickness and color and the presence and absence of a pigmented testa. From this knowledge, several white, tan plant sorghum inbreds have been released to the seed industry and are being grown in the United States. These food hybrids have improved quality for use in livestock feed as well as ingredients in food systems.

Sorghum is used for malting and traditional beverage production in Africa. Malt quality is critically important and limits its use. Methods of determining malting potential of sorghum have been developed and used to show large differences exist among cultivars. Both genetic and environment significantly affect malting properties. Dorado, a white food type sorghum, had the best malting properties. Eco-

nomically, significant differences have been found. Malted sorghum has greatly modified kernel structure which improves its nutritional value significantly.

New prototype food products including noodles, ready-to-eat breakfast foods, weaning foods, granolas, instant porridges, baked products and others have been developed from 100% sorghum and millet for potential utilization in several countries. Products have been made with sophisticated techniques like extrusion and micronizing and also with simple, low-technology methods appropriate to targeted countries. The major constraint limiting their application is the lack of a consistent supply of good quality sorghum and millet grains at a price competitive with imported rice, corn and wheat products. Parboiled sorghum and millet has excellent potential in Mali. Malian sorghum breeders are developing photosensitive sorghums with tan plants to provide a consistent supply of grain for processing.

Sorghum has been used to produce tortilla chips, tortillas and related products from alkaline cooking. Several new cultivars with improved tortilla making quality have been or are near release in Central America because of collaborative work within the breeding programs. A simple test to evaluate tortilla potential of sorghums has been successfully utilized.

New waxy and heterowaxy sorghum cultivars and hybrids have been developed with unique properties for use in food systems. A white, tan waxy sorghum produced flakes for granola using micronizing. These JOWAR flakes have excellent potential for use in a wide variety of products. The same grains have excellent steam flaking properties and may have improved feed efficiency when fed to ruminants and swine.

The adverse effects of molds and weathering on sorghum quality significantly limit the use of sorghum for foods in many areas. Major progress to understand the factors affecting grain deterioration has been made. Work continues to secure mold resistant sorghum cultivars. Some of the new cultivars, i.e., Sureño, Malisor 84-7, have improved resistance to grain deterioration. New information on the role of antimicrobial proteins is being developed. Head bugs and molds are major constraints restricting sorghum improvement in West African countries.

The structure and processing properties of pearl millet has been evaluated. A white pearl millet grain had excellent acceptance when cooked like rice. The milling properties of millet were mainly affected by kernel size, shape and hardness. Parboiled millet did not develop the off-flavor that occurs in millet millet products.

**Host Country Program Enhancement**

*Mali*

The collaborative research on African sorghum head bugs in West Africa, especially Niger and Mali has quantified damage (yield and quality loss); identified resistant genotypes, including practical methodology to screen for resistance; and described bug species composition, biology, and population dynamics. Research in Mali confirmed the resistance of Malisor 84-7 to head bugs. Research on the sugarcane aphid was conducted in Botswana and Zimbabwe, sorghums resistant to this insect were identified, and the mechanisms and inheritance of resistance assessed.

Sorghums accumulating high amounts of proline had significantly greater heat and desiccation tolerance than those that accumulated less proline. Plants grown from seed produced in a stressful area in Mali had more seedling drought resistance than plants grown from seed of the same genotypes produced in a less stressful area. Local Malian sorghums acclimated to environmental stress to a greater degree than introduced genotypes. The evaluation of adaptation to stress in Mali showed that the local Malian sorghums were superior in a combination of several physiological characteristics that were identified as contributing to drought and high temperature resistance.

Research in Mali has shown that grain yields do not always increase with applied N when conditions are extremely dry. However, in the higher rainfall regimes, yield increases are obtained with N application and the local varieties such as Tiemarifing have consistently higher N use efficiency than the improved types such as Malisor 84-7. There appears to be a tremendous need for phosphorus in the sandier soils, and this may be the mineral element which is most limiting in many cases.

Sorghum-peanut intercropping increased the land use efficiency ratio (LER) by 4, 13, and 41% over sole crops at zero, 40 and 90 kg $ha^{-1}$ N, while millet-cowpea intercrop increased the LER BY 29-33% at all N levels. Research in Mali has shown clear yield advantage to rotation of sorghum following peanut and millet following cowpea, and a smaller yield advantage following intercropping.

A food technology laboratory that works closely with the millet and sorghum improvement programs has been developed and equipped. The laboratory has applied several simple techniques developed at Texas A&M to evaluate sorghum and millet for thick porridge quality. Critically important factors like pericarp removal, grain deterioration by head bugs and molds, the effect of plant color and different cultivars on porridge quality were discovered and introduced into the sorghum improvement program.

The food technology laboratory has conducted many village and urban cooking and processing trials of sorghum, millet and legumes. A blend of three parts millet flour and

one part of cowpea flour was shown to work well as an inexpensive weaning food for young children. This technology has been successful in some areas of Mali. Parboiling trials showed the importance of grain with tan plant color to produce improved highly acceptable products. This has led to current objectives to produce an improved local photosensitive sorghum with tan plant color specifically for use in value added processing.

The Malian laboratory found that major constraints to millet quality were seed shape, size and texture. Globular kernels with medium size gave the highest milling yields. Parboiling pearl millet enhanced decortication yields significantly and improved the texture and acceptability while reducing the development of objectionable aromas. Parboiling is a simple technique that can be applied in villages using existing equipment.

The development of new cultivars for use in value-added processing should lead to increased economic activities in Mali.

*Niger*

In pearl millet, the diversity and diallel cross studies indicate clearly that knowledge of the degree of similarity or dissimilarity among landraces is not sufficient when choosing the best parent for crosses. The population crosses Ex-Bornu x P3Kolo gave the highest grain yield and a good level of heterosis even though the cluster analysis showed that the two cultivars had similarities for most of the traits measured.

An integrated sorghum and millet disease research program is in place. Emphasis has been on the biology and control of long smut. Initially, collaboration between workers in Sudan and Niger permitted the rapid transfer of specific technologies. Evaluation of resistance to long smut is an integral part of the Niger sorghum improvement program. Evaluation for resistance to head smut, Acremonium wilt, and anthracnose is also part of this program. Work on the control of downy mildew of pearl millet has been accelerated with the deployment of Apron® plus.

In Honduras and Niger INTSORMIL collaboration has resulted in development of sustainable biological control strategies for stem borers, and information on pest and natural enemy biologies has contributed to improved approaches to IPM. For whorlworms in Honduras, techniques were developed to manipulate key natural enemies; for stem borers in Honduras, an efficient natural enemy was imported, released in Honduras and established; for stem borers in Niger, natural enemies were demonstrated to occur in greater densities in natural vegetation than in millet, a suggestion that the substantial changes to cultivated millet is interfering with biological controls.

In Niger on the sandy dune soils, crusting is usually a less serious problem but the water rapidly infiltrates deeply into the soil so that the plant roots are not able to tap it. Moderate fertilization and higher plant densities have been shown to simultaneously increase soil fertility and water-use efficiency. The research in Niger showed that these crops can gain benefits from added N in either a wet or a dry year. If a legume/cereal rotation is used to obtain "fixed N", then some addition of P is needed to maximize yields. Pearl millet yields increased greatly following a cowpea intercrop or sole crop cowpea. These results demonstrate the importance of a cowpea legume crop and N fertilizer in improving millet yields under the stressful Nigerien conditions.

In the Sudanian zone, as in Burkina Faso, the combined introduction of tied ridges, fertilization, and a new animal traction implement has the economic potential to substantially increase sorghum yields. This higher input system is more sustainable than the deteriorating low input system generally practiced now. The impact of agricultural and household technologies on the welfare of women has been analyzed. With most types of household decision making both types of technologies have substantial positive impacts on female (and household) incomes. INTSORMIL has studied the economic factors influencing the shift from extensive, low input systems, where the principal innovation is animal traction, to intensive systems with purchased input use and improved cultivars. To increase yields profitably it is generally necessary to respond to both the water availability and the soil fertility constraints.

*Sudan*

The economic impacts of Hageen Dura 1, in the Sudan, show substantial returns to agricultural research and extension. The Hageen Dura 1 experience indicates the importance of the expansion of a private seed industry and a fertilizer distribution system to support the rapidly increasing demand for both inputs once a new hybrid is introduced. The extensive, low-input agriculture is not sustainable but leads to soil degradation and declining yields. The use of moderate levels of chemical fertilizer, an improved cultivar, and improved agronomic practices can raise yields and maintain them at 1.2 to 1.4 mt/ha. These are not outstanding sorghum yields internationally but they are a substantial improvement over present yields. These improved technologies were also highly profitable. The potential farmer demand for medium and longer season cultivars and the importance of reducing the cereal price collapse in good rainfall years both became obvious in country studies in Niger and Burkina. In Sudan Hageen Dura 1 diffusion was related to the functioning of the input markets, extension contacts, and farmers' taste preferences. Intensive technologies not only increase yields but are more sustainable systems than the extensive systems presently practiced. Many of these intensive systems are highly profitable and their water-retention features result in little increase in riskiness of the combined systems.

Forage legumes of clitoria (C)*Clitoria ternata* L. and phillipesara (P)*Phasulus trilobus Ait.* in a two-course rota-

tional system greatly increased sorghum yield over that of continuous sorghum. However, clitoria performed better than phillipesara as a previous crop.

Research in Sudan began with the control of charcoal rot, resistance to long smut and related smut diseases and, more recently, on control of anthracnose and downy mildew of pearl millet. Host resistance work for control of charcoal rot and long smut are included as a continuing program in Sudan. Transfer of the inoculation techniques to Niger and elsewhere represents the quality and maturity of the research on sorghum pathology in Sudan.

*Botswana*

Several cultivars with SC326-6 in their genetic background demonstrated good general adaptation to the SADC region and possessed excellent disease resistance needed in some areas of the region (leaf blight and anthracnose). Lines and advanced lines were evaluated and those with potential are being utilized as parental lines. A seed parent from Segaolane has been developed. Variability on both the female and male sides is being used to develop adapted hybrids for Botswana. The pearl millet breeding program has made selections from a Serere 6A population. An advanced improved line from this population is being tested for its potential as a new variety. Identification of resistance to the sugarcane aphid and identification of predators that will attack it have been found.

Pearl millet seed either screened for larger size or produced by partial removal of the head resulted in better establishment and in many cases improved yields. The exception was under extremely severe stress conditions in Botswana. Germination responses of both pearl millet and grain sorghum to temperature and soil moisture have been quantified. Interactive effects between seed quality and environmental conditions were variable. The grain sorghum growth model sorkam was validated, improved and utilized to develop a replant decision to allow for U.S. conditions.

Management practices on water runoff showed if additional water could be diverted to a site, better yields resulted. Practices associated with better water availability must be coupled with the proper plant population and pest control. In the event excess water occurs, the system must be designed to release water without erosion. The National Tillage Trials showed early tillage frequently improved soil water storage. This coupled with fertilizer (15 kg P $ha^{-1}$) generally increased yield. Due to low yield, addition of P was not economical where soil P was greater than 5 mg $kg^{-1}$. Nitrogen was not influential unless the rain was uniformly distributed over the season. However, manure/crop residues were effective in increasing water intake. Manure by itself was quite effective, but combined with residues, intake was even greater.

*Honduras*

Crop mortality factors were partitioned in sorghum-corn intercropping systems in Honduras; 65% mortality was due to insects. Pest species diversity and density levels were cataloged. Seed treatment with insecticide was required to prevent seed and seedling loss due to soil-inhabiting insects and millipedes. Parasites of armyworm species in the langosta complex were identified and their impact quantified. The international significance of a migratory pest species (fall armyworm) was elucidated in comparisons of insect biology, behavior and reaction to insecticides for insect populations from the U.S. and the Latin American Ecogeographic Zone.

Ecological approaches to insect pest management included cultural and biological control and host plant resistance. Honduran native landrace sorghums, "maicillo criollos" with antibiosis insect resistance were identified.

In Honduras the investment in the soil conservation technology made possible the introduction of an intensive technology system (yield increasing) including fertilization, better agronomic practices, and a new cultivar. Honduras farmers are growing Sureño, an improved maicillos, because the grain produces lighter colored tortillas.

*Colombia*

Since 1982, five cultivars, the result of collaboration between ICA, commercial companies, and INTSORMIL, have been released. These cultivars produce profitably in soils with as high as 60% Al saturation, opening up more than 200,000 ha of marginal land in Colombia alone. The two varieties released in 1990, Sorghica Real 40 (156-P5-Serere 1) and Sorghica Real 60 (MN-4508), are tolerant to soils with 40% and 60% Al saturation, respectively. ICA and the El Alcaraván Foundation, with INTSORMIL's support, released in 1993 two lines adapted to Arauca (Colombian Eastern Plains): IS-3071 (Icaraván 1) and IS-8577 (Icaraván 2). These lines have good agronomic characteristics.

Colombia is the only Latin American country where universities, the private sector (El Alcaraván), national research institutions (FENALCE and ICA), and an international center (CIAT) collaborate with INTSORMIL to accomplish research and training goals.

All mineral elements were affected by acid soils stresses, but silicon and calcium in plant tissue were most closely related to acid soil tolerance. An effective laboratory screening technique was devised to screen sorghum seedlings for acid soil tolerance. Studies on mycorrhizal (VAM) colonizations on sorghum showed that VAM associations on roots can assist in the extraction of phosphorus (P) from low P soils. However, the higher the inherent soil P level, the lower the VAM association which occurred.

**Networking**

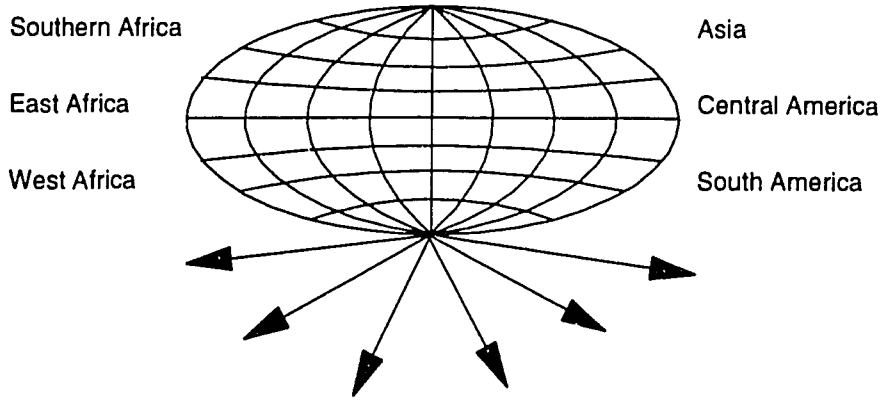
Over the years, established networking activities have continued with ICRISAT, SADC/ICRISAT, SAFGRAD, ICRISAT Sahelian Center, ICRISAT West Africa Sorghum Improvement Program, EARSAM of ICRISAT, ICRISAT/CIMMYT, CLAIS of Central and South America, and CIAT. There has been excellent collaboration with each of these programs in co-sponsoring workshops and conferences, for coordination of research and long term training.

INTSORMIL is working with newly emerging networks, such as ROCAFREMI (INSAH) of West/Central Africa. INTSORMIL plans to strengthen linkages among the NARS it works with, as well as international and regional organizations and networks. INTSORMIL will continue to promote free exchange of germplasm, technical information, improved technology, and research techniques.

**Future Directions**

INTSORMIL will continue to jointly plan and execute collaborative research that benefits developing countries and the United States. These collaborative relationships are keys to INTSORMIL's success and will continue as fundamental approaches to meeting the INTSORMIL mission. In the future, INTSORMIL will target NARS collaborative ties that reflect regional needs for sorghum and/or millet production. These ties are envisioned to be in the sorghum and millet agroecological zones of western, eastern, and southern Africa, and Central America. By concentrating collaboration in selected sites, INTSORMIL optimizes its resources, builds a finite scientific capability on sorghum and millet, and creates technological and human capital that has a sustainable and global impact. INTSORMIL will use four specific strategies to maintain its current momentum, build on its record of success, and accomplish a new set of goals. These strategies are (1) sustainable research institutions and human capital development, (2) conservation of biodiversity and natural resources, (3) research systems development with focus on relevant technology generation, and (4) information and research networking.

# INTSORMIL GLOBAL PLAN



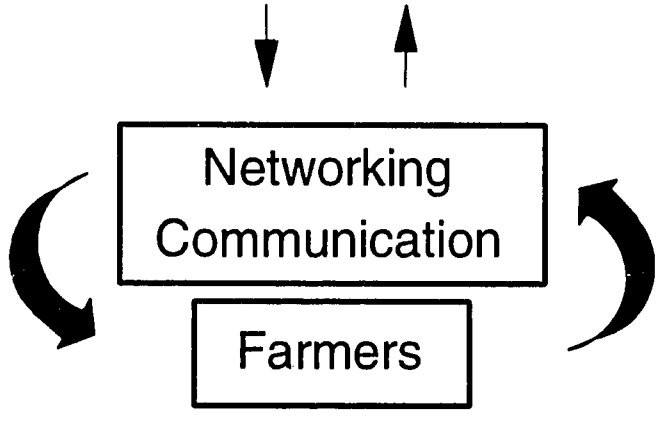

## CONSTRAINTS

## Technical Thrusts

| Germplasm Enhancement | Sustainable Production Systems | Sustainable Plant Protection Systems | Crop Utilization and Marketing |
|---|---|---|---|

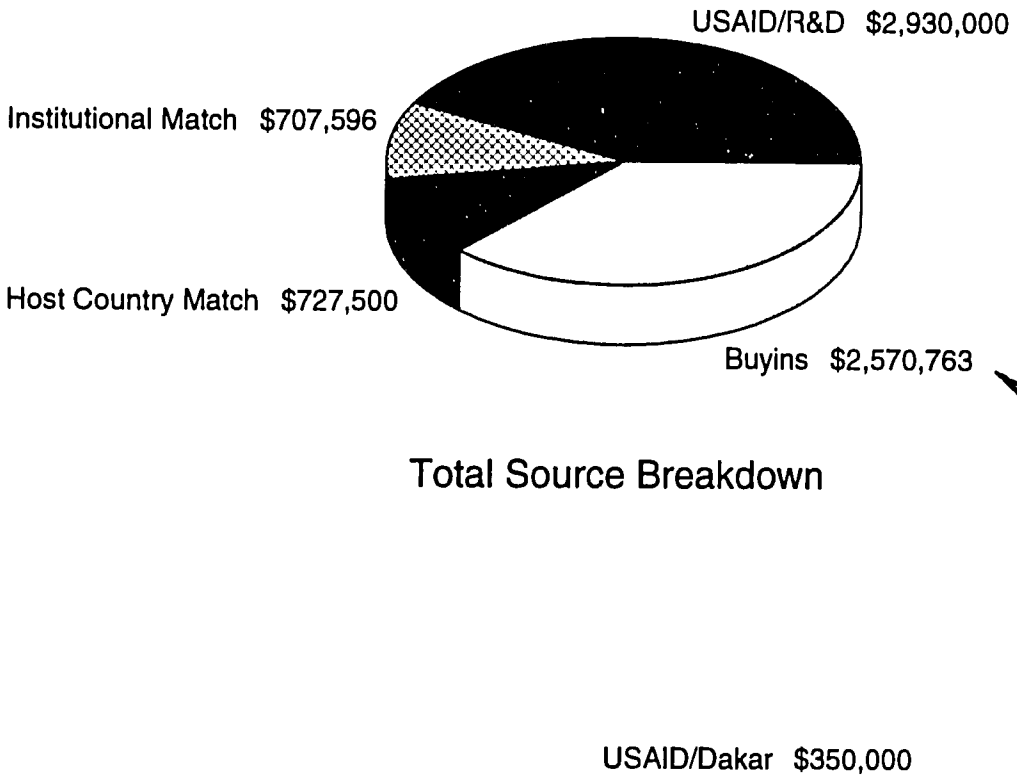
## Research Output

- Collaborative Research Network
- Improved Sustainable Production Systems
- Development and Release of Enhanced Germplasm
- Development of Sustainable Plant Production Systems
- Development of Economic Models for directing prioritization of research and Farmlevel Industry evaluation
- Development of Sustainable Food Technology, processing and marketing systems
- Institutional Strengthening - (operations, training, etc.)
- Networking - Seminars, workshops and confrences

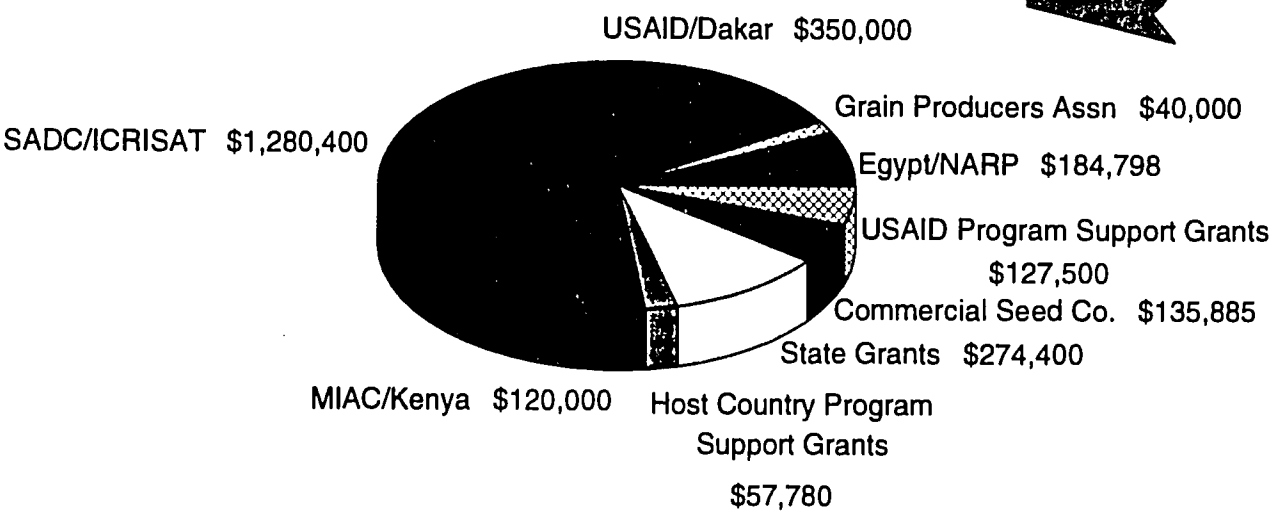


# INTSORMIL Source of Funding

## Total Year 14 Source - $ 6,935,859




Total Source Breakdown

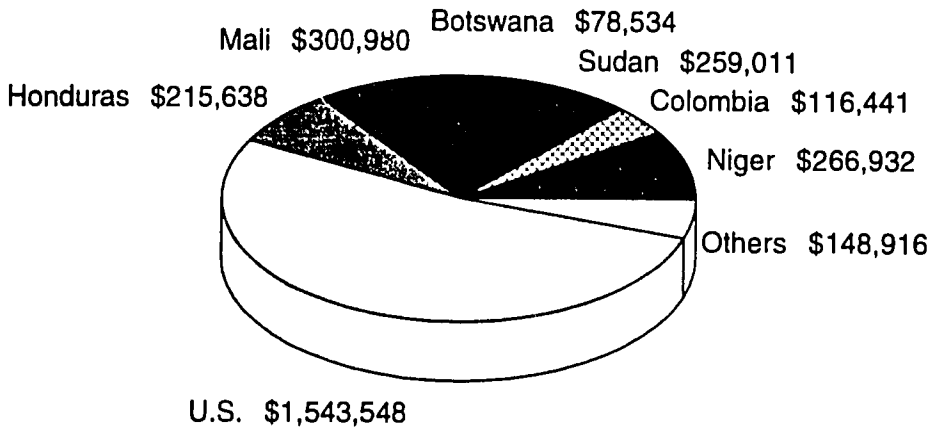



Buyin Breakdown

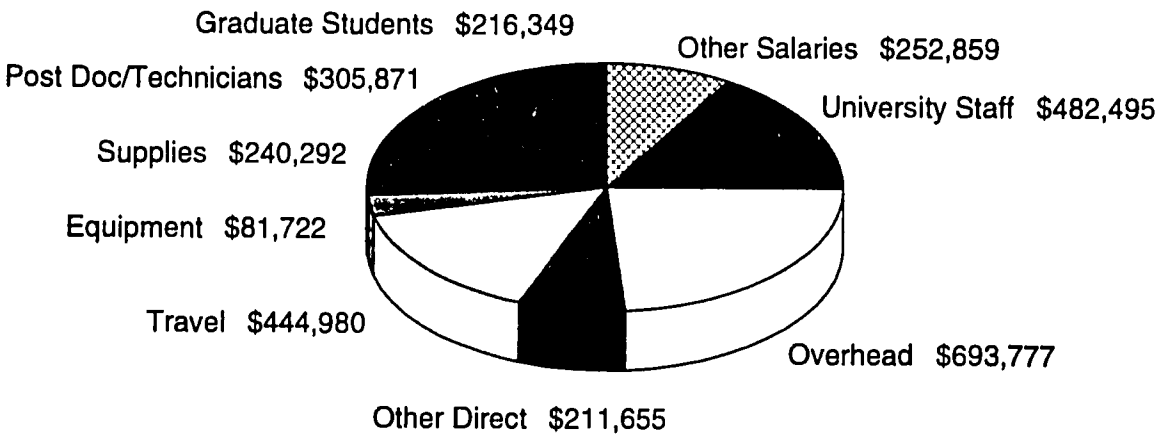
# Year 14 - FY 93

## INTSORMIL Budget Analysis

## Functional - $ 2,930,000



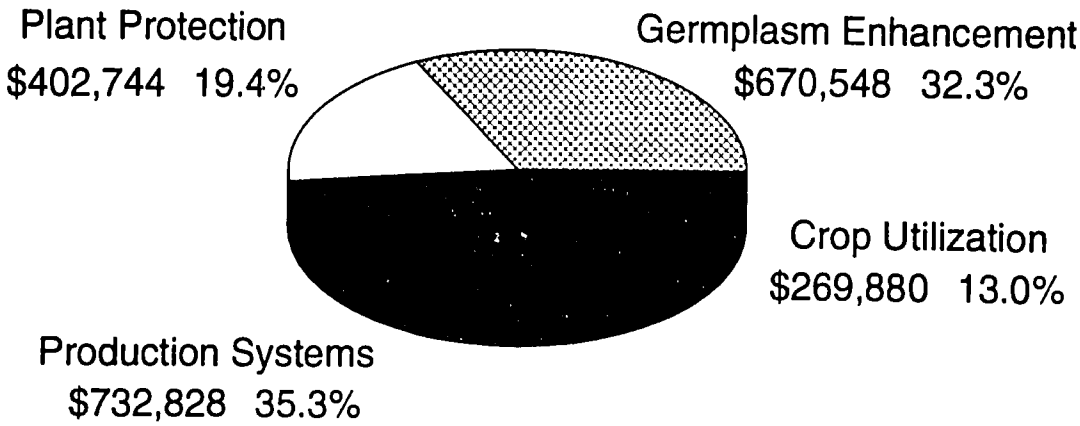

By Country



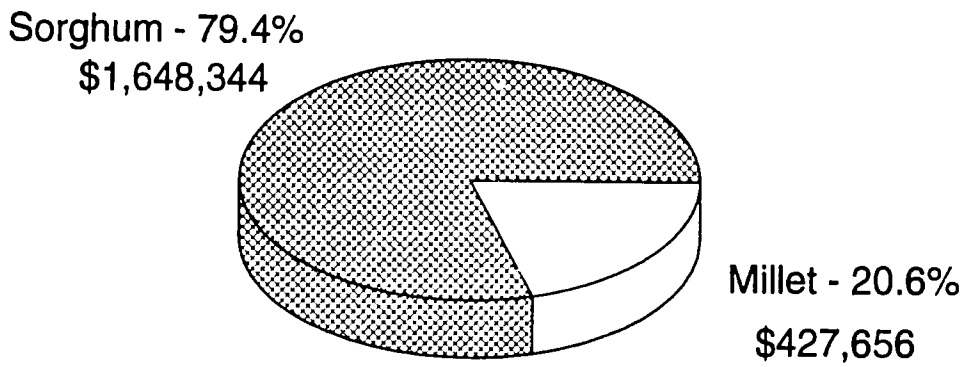

By Line Item

# INTSORMIL FY 93 Budget Analysis

## Technical - $ 2,076,000




By Technical Thrusts




By Crop

**Table 1. USAID-Grant Contribution to Sorghum/Millet CRSP for Years 1 (FY80) through 14 (FY93) for all Collaborative Research and Management Entity.**

| Budget Line Items | FY 80-85 Years 1-6 | FY 86-90 Years 7-11 | FY 91-92 Year 12-13 | FY 93 Year 14 | FY 80-93 Totals |
|---|---|---|---|---|---|
| Salaries & Benefits | $ 7,604,987 | $ 6,237,598 | $ 2,537,101 | 1,257,574 | $ 17,637,260 |
| Equipment & Facilities | 1,292,255 | 634,996 | 130,383 | 81,722 | 2,139,356 |
| Travel | 1,862,258 | 1,572,005 | 589,302 | 289,980 | 4,313,545 |
| Other Direct Costs | 1,018,921 | 1,518,436 | 873,437 | 418,947 | 3,829,741 |
| Technical Assistance | 341,290 | 57,000 | 10,000 | 10,000 | 418,290 |
| LDC Special Projects | 2,160,955 | 1,357,725 | 346,906 | 178,000 | 4,043,586 |
| Indirect Costs | 3,869,334 | 3,353,940 | 1,452,871 | 693,777 | 9,369,922 |
| Total | $ 18,150,000 | $ 14,731,700 | $ 5,940,000 | $ 2,930,000 | $ 41,751,700 |

**Table 2. A.I.D.-Grant Contribution to Sorghum/Millet CRSP for all Collaborative Research, U.S. Institutions (Florida A&M University, University of Arizona, Kansas State University, University of Kentucky, Mississippi State University, University of Nebraska, Purdue University, Texas A&M University), and the Management Entity.**

| Budget Line Items | FL | AZ | KY | KS | MS | NE | PR | TX | Institutional Total | ME Budget | ME TA-LDC | Total Grant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Years 1 - 6 (FY 80-85) A.I.D. Grant - AID/DSAN/XII-G-0149** | | | | | | | | | | | | |
| Salary & Benefits | 85,270 | 191,675 | 287,013 | 896,270 | 828,186 | 1,622,402 | 1,224,363 | 1,833,520 | 6,968,699 | 636,288 | | 7,604,987 |
| Equipment & Facilities | 35,500 | 41,529 | 4,600 | 134,655 | 34,968 | 159,889 | 129,863 | 726,750 | 1,267,754 | 24,501 | | 1,292,255 |
| Travel | 14,500 | 27,523 | 136,390 | 276,950 | 177,094 | 233,533 | 216,753 | 435,559 | 1,518,302 | 343,956 | | 1,862,258 |
| Other Direct Costs | 7,500 | 5,670 | 55,271 | 142,027 | 112,537 | 148,359 | 217,751 | 242,370 | 931,485 | 87,436 | | 1,018,921 |
| Technical Assistance | | | | | | | | | | | | |
| LDC | | | | | | | | | | | 341,290 | 341,290 |
| Indirect Costs | 35,106 | 58,283 | 165,476 | 397,575 | 447,465 | 762,315 | 661,080 | 894,215 | 3,421,515 | 447,819 | 2,160,955 | 2,160,955 |
| TOTALS | $ 177,876 | $ 324,680 | $ 648,750 | $ 1,847,477 | $ 1,600,250 | $ 2,926,498 | $ 2,449,810 | $ 4,132,414 | $ 14,107,755 | $ 1,540,000 | $ 2,502,245 | $ 18,150,000 |
| **Years 7 - 11 (FY 86-90) A.I.D. Grant - AID/DAN-1254-G-SS-5065-00** | | | | | | | | | | | | |
| Salary & Benefits | | | 100,954 | 754,097 | 532,584 | 1,044,184 | 1,324,037 | 1,718,681 | 5,474,537 | 763,061 | | 6,237,598 |
| Equipment & Facilities | | | 800 | 90,817 | 79,347 | 170,837 | 95,802 | 185,210 | 622,813 | 12,183 | | 634,996 |
| Travel | | | 27,684 | 165,613 | 131,996 | 199,309 | 353,523 | 405,880 | 1,284,005 | 288,000 | | 1,572,005 |
| Other Direct Costs | | | 17,213 | 116,960 | 148,757 | 202,525 | 366,378 | 483,008 | 1,334,841 | 161,595 | 22,000 | 1,518,436 |
| Technical Assistance | | | | | | | | | | | 57,000 | 57,000 |
| LDC | | | | | | | | | | | 1,265,525 | 1,265,525 |
| Discontinued Projects and Grad Student Support | | | | | | | | | | | | |
| Indirect Costs | | | 54,999 | 319,538 | 265,566 | 544,370 | 811,010 | 901,296 | 2,896,779 | 457,161 | 92,200 | 92,200 |
| TOTALS | | | $ 201,650 | $ 1,447,025 | $ 1,158,250 | $ 2,161,225 | $ 2,950,750 | $ 3,694,075 | $ 11,612,975 | $ 1,682,000 | $ 1,436,725 | $ 3,353,940 |
| | | | | | | | | | | | | $ 14,731,700 |
| **Year 12 - 13 (FY 91-92) A.I.D. Grant - AID/DAN-1254-G-00-0021-00** | | | | | | | | | | | | |
| Salary & Benefits | | | | 278,536 | 229,691 | 403,656 | 504,097 | 693,421 | 2,109,401 | 427,700 | | 2,537,101 |
| Equipment & Facilities | | | | 15,487 | 5,081 | 32,148 | 33,300 | 41,167 | 127,183 | 3,200 | | 130,383 |
| Travel | | | | 33,000 | 53,085 | 74,040 | 149,257 | 202,920 | 512,302 | 77,000 | | 589,302 |
| Other Direct Costs | | | | 64,451 | 68,758 | 88,784 | 378,198 | 216,506 | 816,697 | 56,740 | | 873,437 |
| Technical Assistance | | | | | | | | | | | 106,800 | 106,800 |
| LDC/Special Projects* | | | | | | | | | | | 250,106 | 250,106 |
| Indirect Costs | | | | 120,926 | 111,885 | 191,372 | 404,148 | 413,986 | 1,242,317 | 210,554 | | 1,452,871 |
| TOTALS | | | | $ 512,400 | $ 468,500 | $ 790,000 | $ 1,469,000 | $ 1,568,000 | $ 4,807,900 | $ 775,194 | $ 356,906 | $ 5,940,000 |
| **Year 14 (FY93) A.I.D. Grant - AID/DAN-1254-G-00-0021-00 (July 1, 1992 - June 30, 1993)** | | | | | | | | | | | | |
| Salary & Benefits | | | | 77,341 | 136,282 | 186,114 | 266,995 | 341,042 | 1,007,774 | 226,800 | | 1,234,574 |
| Equipment & Facilities | | | | 3,651 | 2,165 | 21,256 | 2,000 | 24,500 | 53,572 | 1,650 | | 55,222 |
| Travel | | | | 15,000 | 18,350 | 38,552 | 57,504 | 103,074 | 232,480 | 33,500 | | 265,980 |
| Other Direct Costs | | | | 13,658 | 20,121 | 81,877 | 136,462 | 111,329 | 363,447 | 29,000 | | 392,447 |
| Technical Assistance | | | | | | | | | | | 10,000 | 10,000 |
| LDC Special Projects | | | | | | | | | | | 278,000 | 278,000 |
| Indirect Cost | | | | 45,350 | 58,082 | 97,201 | 177,039 | 209,055 | 586,727 | 107,050 | | 693,777 |
| TOTALS | | | | $ 155,000 | $ 235,000 | $ 425,000 | $ 640,000 | $ 789,000 | $ 2,244,000 | $ 398,000 | $ 288,000 | $ 2,930,000 |
| GRAND TOTALS | $ 177,876 | $ 324,680 | $ 850,400 | $ 3,961,902 | $ 3,462,000 | $ 6,302,723 | $ 7,509,560 | $ 10,183,489 | $ 32,772,630 | $ 4,395,194 | $ 4,583,876 | $ 41,751,700 |

*LDC and Special Projects/External Evaluation Panel, Mali/Niger Country Projects

**Table 3. Management Entity Office Budget Details.**

| Budget Line Items | FY 80-85 Years 1-6 | FY 86-90 Years 7-11 | FY 91-92 Year 12-13 | FY 93 Year 14 | Totals FY 80-93 Years 1-14 |
|---|---|---|---|---|---|
| Salaries & Benefits | $ 636,288 | $ 763,061 | $ 423,700 | 226,800 | $ 2,049,849 |
| Equipment & Facilities | 24,501 | 12,183 | 3,200 | 1,650 | 41,534 |
| Travel | 339,956 | 257,000 | 77,000 | 33,500 | 707,456 |
| International | | | | 10,000 | |
| Domestic | | | | 4,400 | |
| Board of Directors | | | | 5,300 | |
| Technical Committee | | | | 6,400 | |
| Ecogeographic Zone Committee | | | | 7,400 | |
| Consultants | 6,600 | 22,000 | 8,000 | 4,000 | 40,600 |
| Other Direct Costs | 84,836 | 144,595 | 52,740 | 25,000 | 307,171 |
| Indirect Costs | 447,819 | 457,161 | 210,554 | 107,050 | 1,222,584 |
| Total | $ 1,540,000 | $ 1,656,000 | $ 775,194 | 398,000 | $ 4,369,194 |
| P.I. Conference | | 16,000 | 25,000 | | 41,000 |
| External Evaluation Panel | | 10,000 | 30,000 | 65,000 | 105,000 |
| Special Projects | | | | 113,000 | 113,000 |
| ME Total Costs | $ 1,540,000 | 1,682,000 | $ 830,194 | $ 576,000 | $ 4,628,194 |

**Table 4. Sorghum/Millet CRSP Summary of Non-Federal Matching Contributions by U.S. Institutions - Grant Years 1 (FY 80) through 14 (FY 93).**

| U.S. Institution | FY 80-92 Years (1-13) | FY 93 Year 14 | FY 80-93 Totals |
|---|---|---|---|
| University of Arizona | $ 149,310 | $ | $ 149,310 |
| Florida A&M University | 23,898 | | 23,898 |
| University of Kentucky | 215,649 | | 215,649 |
| Kansas State University | 1,439,958 | 166,043 | 1,606,001 |
| Mississippi State University | 811,119 | 17,500 | 828,619 |
| University of Nebraska | 1,780,766 | 90,550 | 1,871,316 |
| Purdue University | 1,994,900 | 170,685 | 2,165,585 |
| Texas A&M University | 3,344,833 | 262,818 | 3,607,651 |
| Total | $ 9,760,433 | $ 707,596 | $ 10,468,029 |

# Year 14 INTSORMIL Training Participants

| Name | Country | Univ. | Discipline | Advisor | Degree | Gender | Funding* |
|---|---|---|---|---|---|---|---|
| Gono, Lawrence | Zimbabwe | KSU | Agronomy | Vanderlip | PHD | M | S |
| Heiniger, Ronnie | U.S. | KSU | Agronomy | Vanderlip | PHD | M | I |
| Lele, Etani | Botswana | KSU | Agronomy | Vanderlip | MSC | M | S |
| Madulu, Ruth | Tanzania | KSU | Agronomy | Vanderlip | MSC | F | S |
| Gutierrez, Patricio F. | Ecuador | UNL | Agronomy | Clegg | MSC | M | I |
| Maliro, Charles | Malawi | UNL | Agronomy | Clegg | PHD | M | S |
| Mohamed, Mirghani S. | Sudan | UNL | Agronomy | Clegg | PHD | M | I |
| Buah, Samuel | Ghana | UNL | Agronomy | Maranville/Andrews | MSC | M | O |
| Masi, Cassim | Zambia | UNL | Agronomy | Maranville | PHD | M | S |
| Rivera, Roberto | Honduras | UNL | Agronomy | Maranville | PHD | M | O |
| Traore, Abdoulaye | Mali | UNL | Agronomy | Maranville | PHD | M | I |
| Wu, Yi | China | UNL | Agronomy | Maranville | PHD | F | O |
| Rao, Aluri Sambosiva | India | KSU | Breeding | Stegmeier | VS[1] | M | I |
| Goggi, Susani | Argentina | MSU | Breeding | Gourley | PD[2] | F | I |
| Zake, Vincent | Uganda | MSU | Breeding | Gourley | PHD | M | O |
| Kapran, Issoufou | Niger | PRF | Breeding | Axtell | PHD | M | P |
| Peters, Paul | U.S. | PRF | Breeding | Axtell | PHD | M | P |
| Cisse, N'Diaga | Senegal | PRF | Breeding | Ejeta | PHD | M | O |
| Grote, Ed | U.S. | PRF | Breeding | Ejeta | PHD | M | O |
| Ibrahim, Yahia | Sudan | PRF | Breeding | Ejeta | MSC | M | O |
| Johnson, Richard | U.S. | PRF | Breeding | Ejeta | MSC | M | O |
| Menkir, Abebe | Ethiopia | PRF | Breeding | Ejeta | PD[2] | M | O |
| Tuinstra, Mitchell | U.S. | PRF | Breeding | Ejeta | PHD | M | O |
| Vogler, Renee | U.S. | PRF | Breeding | Ejeta | MSC | F | I |
| Weerasuriya, Yohan | Sri Lanka | PRF | Breeding | Ejeta | PHD | M | O |
| Gouveia, Sergio Jeremias | Mozambique | TAM | Breeding | Miller/Rosenow | MSC | M | P |
| Nesbitt, T. Clint | U.S. | TAM | Breeding | Miller | MSC | M | P |
| Ombakho, George | Kenya | TAM | Breeding | Miller/Rosenow | PHD | M | P |
| Palma Carias, Alejandro | Honduras | TAM | Breeding | Miller | MSC | M | P |
| Stewart, Klint G. | U.S. | TAM | Breeding | Miller | MSC | M | P |
| Tenkouano, Abdou | Burkina Faso | TAM | Breeding | Miller | PHD | M | P |
| Crasta, Oswald | India | TAM | Breeding | Rosenow | PHD | M | P |
| Mkhabela, Milton | Swaziland | TTU | Breeding | Rosenow | PHD | M | S |
| Munera, Alvaro | Colombia | TTU | Breeding | Rosenow | MSC | M | P |
| Doumbia, Mamadou | Mali | TAM | Breeding | Peterson/Onken | PHD | M | O |
| Jeutong, Fabien | Cameroon | UNL | Breeding | Andrews | PHD | M | O |
| Kiula, Barnabas | Tanzania | UNL | Breeding | Andrews | MSC | M | S |
| Mahama, A. Assibi | Ghana | UNL | Breeding | Andrews | MSC | M | O |
| Muza, F.R. | Zimbabwe | UNL | Breeding | Andrews | PHD | M | S |
| Ahmed, Mohamed | Sudan | PRF | Economics | Sanders | PHD | M | I |
| Coulibaly, Ousmane | Mali | PRF | Economics | Sanders | PHD | M | I |
| Garcia, Joao Carlos | Brazil | PRF | Economics | Sanders | VS[1] | M | O |
| Lawrence, Pareena Gupta | U.S. | PRF | Economics | Sanders | PHD | F | P |
| Nichola, Tennassie | Ethiopia | PRF | Economics | Sanders | PHD | M | I |
| Ching'oma, Godfrey | Malawi | MSU | Entomology | Pitre | MSC | M | S |
| Lopez, Julio | Honduras | MSU | Entomology | Pitre | MSC | M | I |
| Portillo, Hector | Honduras | MSU | Entomology | Pitre | PHD | M | I |
| Bayoum, Imad | Lebanon | TAM | Entomology | Gilstrap | PHD | M | P |
| Behle, Robert | U.S. | TAM | Entomology | Gilstrap | PHD | M | I |
| Ciomperlik, Matthew | U.S. | TAM | Entomology | Gilstrap | PHD | M | P |
| Rao, Asha | India | TAM | Entomology | Gilstrap | MSC | F | I |
| Roque, Javier | Mexico | TAM | Entomology | Gilstrap | PHD | M | P |
| Diarisso Yaro, Niamoye | Mali | TAM | Entomology | Teetes | PHD | F | O |
| Jimenez, Nora | Colombia | TAM | Entomology | Teetes | MSC | F | P |
| Jost, Douglas | U.S. | TAM | Entomology | Teetes | MSC | M | I |
| Magallenes, Ricardo | Mexico | TAM | Entomology | Teetes | PHD | M | P |
| Paliani, Anderson | Malawi | TAM | Entomology | Teetes | MSC | M | S |
| Pendleton, Bonnie | U.S. | TAM | Entomology | Teetes | PHD | F | P |
| Lelong, Dolly Bell | Tanzania | PRF | Food Quality/Util | Butler | PHD | F | O |
| Siame, Anthony Bupe | Zambia | PRF | Food Quality/Util | Butler | PHD | M | S |
| Tarimo, Thadeo | Tanzania | PRF | Food Quality/Util | Butler | PHD | M | S |
| Aboubacar, Adam | U.S. | PRF | Food Quality/Util | Hamaker | MSC | M | O |
| Mamadou, Lewamy | Niger | PRF | Food Quality/Util | Hamaker | MSC | M | O |
| Oria, Maria P. | Spain | PRF | Food Quality/Util | Hamaker | PHD | F | I |

| Name | Country | Univ. | Discipline | Advisor | Degree | Gender | Funding* |
|---|---|---|---|---|---|---|---|
| Weaver, Charlotte | U.S. | PRF | Food Quality/Util | Hamaker | MSC | F | I |
| Anderson, Brian | U.S. | TAM | Food Quality/Util | Rooney | MSC | M | P |
| Beta, Trust | Zimbabwe | TAM | Food Quality/Util | Rooney | MSC | F | S |
| Cruz y Celis, Laura | Mexico | TAM | Food Quality/Util | Rooney | MSC | F | P |
| Floyd, Cherie | U.S. | TAM | Food Quality/Util | Rooney | MSC | M | P |
| Hugo, Leda | Mozambique | TAM | Food Quality/Util | Rooney | MSC | F | S |
| Islas-Rubio, Alma | Mexico | TAM | Food Quality/Util | Rooney | PHD | F | P |
| Lekalake, Rosemary | Botswana | TAM | Food Quality/Util | Rooney | MSC | F | S |
| Mireles, Raquel | U.S. | TAM | Food Quality/Util | Rooney | MSC | F | P |
| Mrema, Greyson | Tanzania | TAM | Food Quality/Util | Rooney | MSC | M | S |
| Suhendro, Elly | Indonesia | TAM | Food Quality/Util | Rooney | MSC | F | O |
| Wright, Lee | U.S. | TAM | Food Quality/Util | Rooney | MSC | M | P |
| Diourte, Mamourou | Mali | KSU | Pathology | Claflin | PHD | M | O |
| Muriithi, Linus M. | Kenya | KSU | Pathology | Claflin | PHD | M | O |
| Anderson, Cindy | U.S. | KSU | Pathology | Leslie | M.S. | F | O |
| Huss, Martin | U.S. | KSU | Pathology | Leslie | PD[2] | M | P |
| Xu, Jin-Rong | China | KSU | Pathology | Leslie | PHD | M | P |
| Oh, B.J. | Korea | TAM | Pathology | Frederiksen | PHD | M | O |
| Rosewich, Ute L. | Germany | TAM | Pathology | Frederiksen | PHD | F | I |
| Guthrie, Phillip | Great Britain | TAM | Pathology | Odvody/Frederiksen | PHD | M | I |
| Mansuetus, Anaclet | Tanzania | TAM | Pathology | Odvody/Frederiksen | PHD | M | S |
| Alexander, John | U.S. | TAM | Pathology | Toler | PHD | M | O |
| Gandoul, Gandoul I. | Sudan | UNL | Physiology | Eastin | PHD | M | I |
| Kubic, Keith | U.S. | UNL | Physiology | Eastin | PHD | M | P |
| Ngulube-Msikita, Rachel | Zambia | UNL | Physiology | Eastin | MSC | F | S |
| Nyakatawa, Ermson | Zimbabwe | UNL | Physiology | Eastin | MSC | M | S |

* I = Completely funded by INTSORMIL
P = Partially funded by INTSORMIL
S = SADC/ICRISAT funded
O = Other source

[1]VS = Visiting Scientist
[2]PD = Post Doctoral

KSU = Kansas State University
MSU = Mississippi State University
PRF = Purdue University
TAM = Texas A&M University
TTU = Texas Tech University
UNL = University of Nebraska - Lincoln

# Year 14 SADC/ICRISAT Training Participants

| Name | Country | University | Discipline | Advisor | Degree | Gender |
|---|---|---|---|---|---|---|
| Alfredo, Manuel | Angola | Vicosa | Pathology | Ferreira da Silva | MSC | M |
| Chitengue, Jone | Angola | Vicosa | Breeding | Vieira | MSC | M |
| Domingos, M'panzo | Angola | Vicosa | Agronomy | Nogueira Fontes | MSC | M |
| Jose, Joao | Angola | Vicosa | Breeding | Cardosa | MSC | M |
| Lekalake, Rosemary | Botswana | TAM | Food Science | Rooney | MSC | F |
| Lele, Etani | Botswana | KSU | Agronomy | Vanderlip | MSC | M |
| Makhwaje, Ernest | Botswana | KSU | FSR/Econ | Norman | MSC | M |
| Malepa, Dollina | Botswana | UNL | Plant/Soil | Walters | PHD | F |
| Molapong, Keoagile | Botswana | N. Carolina St. | Plant/Soil | Cox | PHD | M |

| Name | Country | University | Discipline | Advisor | Degree | Gender |
|---|---|---|---|---|---|---|
| Khalema, Tieiso | Lesotho | Texas Tech | FSR/Econ | Ervin | MSC | M |
| Mokhoro, Cyprian | Lesotho | UNL | Food Science | Jackson | MSC | M |
| Ranthamane, Matla | Lesotho | KSU | Breeding | Bramel-Cox | MSC | M |
| Sefika, Phakiso | Lesotho | UNL | Forages | Anderson, B. | MSC | M |
| Ching'oma, Godfrey | Malawi | MSU | Entomology | Pitre | MSC | M |
| Maliro, Charles | Malawi | UNL | Agronomy | Clegg | PHD | M |
| Paliani, Anderson | Malawi | TAM | Entomology | Teetes | MSC | M |
| Brito, Rui | Mozambique | CSU | Agronomy | Durnford | PHD | M |
| Gouveia, Sergio | Mozambique | TAM | Breeding | Miller | MSC | M |
| Hugo, Leda | Mozambique | TAM | Food Science | Rooney | MSC | F |
| Maposse, Inacio | Mozambique | UNL | Forages | Anderson, B. | MSC | M |
| Mucavele, Firmino | Mozambique | Florida | FSR/Econ | Spreen | PHD | M |
| Mabuza, Khanyisile | Swaziland | Guelph | Food Science | Gullet | MSC | F |
| Malaza, Millicent | Swaziland | Penn St. | FSR/Econ | Warland | PHD | F |
| Matsebula, Sebenzile | Swaziland | Saskatchewan | Biometrics | Baker | PHD | F |
| Mkhabela, Milton | Swaziland | Texas Tech | Breeding | Rosenow/Nguyen | PHD | M |
| Felix, Joel | Tanzania | PRF | Agronomy | Vorst | MSC | M |
| Kaganda, Suleiman | Tanzania | UNL | Forages | Anderson/Moser | MSC | M |
| Kiula, Barnabas | Tanzania | UNL | Breeding | Andrews | MSC | M |
| Madulu, Ruth | Tanzania | KSU | Agronomy | Vanderlip | MSC | F |
| Mansuetus, Anaclet | Tanzanaia | TAM | Pathology | Fredriksen | PHD | M |
| Matowo, Peter | Tanzania | KSU | Agronomy | Pierzwnski | PHD | M |
| Mbuya, Odemari | Tanzania | Florida | Agronomy | Boote | PHD | M |
| Mrema, William | Tanzania | TAM | Food Science | Rooney | MSC | M |
| Mtwaenzi, Hamis | Tanzania | MSU | Weed Science | Coats | MSC | M |
| Tarimo, Thadeo | Tanzania | PRF | Bird Control | Butler/Weeks | PHD | M |
| Chisi, Medson | Zambia | KSU | Breeding | Bramel-Cox | PHD | M |
| Hikeezi, Doreen | Zambia | KSU | Food Science | Walker | MSC | F |
| Masi, Cassim | Zambia | UNL | Agronomy | Maranville | PHD | M |
| Mwale, Moses | Zambia | UNL | Plant/Soil | Walters | MSC | M |
| Ngulube-Msikita, Rachel | Zambia | UNL | Breeding | Moser | BSC | F |
| Siame, Anthony | Zambia | PRF | Food Science | Butler | PHD | M |
| Beta, Trust | Zimbabwe | TAM | Food Science | Rooney | MSC | F |
| Gono, Tigere Lawrence | Zimbabwe | KSU | Agronomy | Vanderlip | PHD | M |
| Mahuku, George | Zimbabwe | Guelph | Pathology | Hall | PHD | M |
| Makaudze, Ephias | Zimbabwe | TAM | FSR/Econ | Fuller | MSC | M |
| Mazhangara, Edward | Zimbabwe | PRF | FSR/Econ | Masters | MSC | M |
| Muza, Figuhr | Zimbabwe | UNL | Breeding | Lee | PHD | M |
| Nyakatawa, Ermson | Zimbabwe | UNL | Agronomy | Eastin/Schilling | MSC | M |

CSU = Colorado State University, Fort Collins, Colorado
KSU = Kansas State University, Manhattan, Kansas
MSU= Mississippi State University, Mississisippi State, Mississippi
PRF = Purdue University, West Lafayette, Indiana
TAM= Texas A&M University, College Station, Texas
UNL = University of Nebraska, Lincoln, Nebraska

Florida = University of Florida, Gainesville, Florida
Guelph = University of Guelph, Ontario, Canada
N. Carolina St. = North Carolina State University, Raleigh, North Carolina
Penn St. = Penn State University, University Park, Pennsylvania
Saskatchewan = University of Saskatchewan, Saskatoon, Canada
So. Illinois = Southern Illinois University, Carbondale, Illinois
Texas Tech = Texas Tech University, Lubbock, Texas
Vicosa = Universidad Federal de Vicosa, Brazil

# 1993
# INTSORMIL Buy-Ins

| University/ Project No. | Buy-In | Year | Life of Buy-In | Annual Amount | Total |
|---|---|---|---|---|---|
| KSU-106 | Kansas Sorghum Board | 1985 | 6 years | 17,500 | 105,000 |
| | Kansas Agric. Exp. Station | 1989 | 3 years | 19,000 | 57,000 |
| | Kansas Agric. Exp. Station | 1989 | 3 years | 13,333 | 40,000 |
| | Kansas Sorghum Board | 1991 | 4 years | 15,334 | 61,338 |
| | Kansas Agric. Exp. Station | 1990 | 3 years | 19,000 | 57,000 |
| | EPA/Univ. of Nebraska | 1990 | 2 years | 32,518 | 65,036 |
| | | | | | **$ 385,374** |
| KSU-108 | Kansas Sorghum Board | 1985 | 9 years | 18,482 | 166,338 |
| | Kansas Corn Commission | 1988 | 3 years | 16,845 | 50,535 |
| | Kansas Sorghum Commission | 1989 | 1 year | 7,166 | 7,166 |
| | Kansas Sorghum Commission | 1989 | 1 year | 6,500 | 6,500 |
| | EPA | 1990 | 3 years | 39,523 | 118,569 |
| | Kansas Agric. Exp. Station | 1991 | 3 years | 19,000 | 57,000 |
| | USDA/ARS | 1992 | 1 year | 14,400 | 14,400 |
| | | | | | **$ 420,508** |
| MSU-104 | MIAC/Kenya | 1990 | 2 years | 115,725 | 231,450 |
| | MIAC/Kenya | 1992 | 3.5 years | 142,000 | 497,000 |
| | | | | | **$ 728,450** |
| MSU-105 | FAO | 1992 | 3 years | 2,245 | **$ 6,735** |
| MSU-111 | Fedearroz | 1990 | 5 years | 10,000 | 50,000 |
| | El Alcaravan Foundation | 1990 | 2 years | 200,000 | 400,000 |
| | Fenalce | 1991 | 1 year | 5,000 | 5,000 |
| | | | | | **$ 455,000** |
| PRF-103A | AID/Program Support Grant | 1988 | 2 years | 7,500 | 15,000 |
| | Agric. Exp. Station | 1988 | 2 years | 6,000 | 12,000 |
| | Purdue Agronomy Dept. | 1989 | 2 years | 1,000 | 2,000 |
| | McKnight Foundation | 1989 | 3 years | 250,000 | 750,000 |
| | Corporation for Science & Tech. | 1991 | 1 year | 10,000 | 10,000 |
| | Pioneer Hi-Bred Intern. | 1992 | 3 years | 33,900 | 101,693 |
| | Purdue Agronomy Dept. | 1992 | 1 year | 1,000 | 1,000 |
| | McKnight Foundation | 1992 | 3 years | 250,000 | 750,000 |
| | | | | | **$ 1,641,693** |
| PRF-103B | USDA Training | 1989 | 3 years | 15,000 | 45,000 |
| | AFGRAD Training | 1989 | 4 years | 9,000 | 36,000 |
| | NAAR Project | 1991 | 1 year | 3,000 | 3,000 |
| | | | | | **$ 84,000** |
| PRF-104B & 104C | USAID PSG | 1989 | 2 years | 7,500 | 15,000 |
| | Rockefeller Foundation | 1989 | 3 years | 23,067 | 69,200 |
| | USAID/PSTC | 1990 | 4 years | 37,450 | 150,000 |
| | USAID PSG | 1991 | 2 years | 10,000 | 20,000 |
| | Purdue Research Foundation | 1991 | 1 year | 2,800 | 2,800 |
| | Pioneer Seed Co. | 1991 | 3 years | 40,000 | 120,000 |
| | PSTC/USAID | 1991 | 3 years | 50,000 | 150,000 |
| | Pioneer Seed Co. | 1991 | 2 years | 30,000 | 60,000 |
| | NSF | 1992 | 1.5 years | 173,333 | 260,000 |
| | | | | | **$ 847,000** |
| PRF-105 | USAID PSG | 1989 | 4 years | 5,000 | 20,000 |
| | USAID PSG | 1989 | 3 years | 5,000 | 15,000 |
| | World Bank | 1989 | 2.5 years | 10,000 | 25,000 |
| | World Bank/IDA | 1989 | 1 year | 4,500 | 4,500 |
| | USAID/Bean-Cowpea CRSP | 1990 | 1 year | 27,000 | 27,000 |
| | EMBRAPA | 1992 | 1 year | 10,000 | 10,000 |
| | USAID/AFT/ARTS | 1992 | 1 year | 20,000 | 20,000 |
| | | | | | **$ 121,500** |

| University/ Project No. | Buy-In | Year | Life of Buy-In | Annual Amount | Total |
|---|---|---|---|---|---|
| PRF-107 | Purdue Agronomy Dept. | 1988 | 1 year | 1,500 | 1,500 |
| | State of Indiana | 1990 | 1 year | 7,000 | 7,000 |
| | McKnight Foundation | 1990 | 3 years | 20,632 | 61,896 |
| | USAID PSG | 1990 | 2 years | 14,000 | 28,000 |
| | McKnight Foundation | 1990 | 3 years | 22,000 | 66,000 |
| | Pioneer Seed Co. | 1991 | 2 years | 30,000 | 60,000 |
| | State of Indiana | 1991 | 1 year | 1,200 | 1,200 |
| | | | | | **$ 225,596** |
| PRF-109 | USDA Grant | 1990 | 2 years | 60,000 | **$ 120,000** |
| TAM Joint | USAID/TAMU | 1989 | 3 years | 15,000 | 45,000 |
| | USAID/TAMU | 1991 | 3 years | 15,000 | 45,000 |
| | | | | | **$ 90,000** |
| TAM-122 | State of Texas Grant | 1989 | 2 years | 20,000 | 40,000 |
| | USAID/TAMU | 1990 | 2 years | 10,000 | 20,000 |
| | USAID/TAMU | 1990 | 3 years | 13,000 | 39,000 |
| | Texas Higher Coordinating Board | 1991 | 2 years | 27,000 | 54,000 |
| | USDA | 1991 | 2 years | 7,500 | 15,000 |
| | USAID/TAMU | 1992 | 2 years | 28,000 | 56,000 |
| | | | | | **$ 224,000** |
| TAM-123 | Texas Grain Sorghum Producers | 1990 | 5 years | 50,000 | 250,000 |
| | USAID/TAMU | 1990 | 1 year | 17,000 | 17,000 |
| | USAID/TAMU | 1991 | 1 year | 28,000 | 28,000 |
| | | | | | **$ 295,000** |
| TAM-124 | USDA | 1989 | 3 years | 10,000 | 30,000 |
| | Texas Advanced Research | 1989 | 1 year | 75,000 | 75,000 |
| | TAES/ERA | 1989 | 2 years | 32,000 | 64,000 |
| | Texas Advanced Research | 1990 | 3 years | 15,000 | 45,000 |
| | Rockefeller Foundation | 1990 | 2 years | 30,000 | 60,000 |
| | Texas Advanced Research | 1992 | 2 years | 10,000 | 20,000 |
| | Rockefeller Foundation | 1992 | 2 years | 7,000 | 14,000 |
| | | | | | **$ 308,000** |
| TAM-125 | TAMU/PSG | 1989 | 2 years | 45,000 | 90,000 |
| | Industry Grant | 1989 | 2 years | 10,000 | 20,000 |
| | USDA/CRSP | 1989 | 1 year | 15,000 | 15,000 |
| | USDA/APHIS | 1989 | 2 years | 15,000 | 30,000 |
| | USDA/APHIS | 1989 | 1 year | 14,000 | 14,000 |
| | Texas Agric. Exp. Station | 1990 | 2 years | 7,000 | 14,000 |
| | USDA/APHIS | 1990 | 3 years | 23,734 | 71,202 |
| | USDA/CSRS | 1990 | 2 years | 59,819 | 119,638 |
| | TAMU/Program Support Grant | 1990 | 2 years | 18,638 | 37,276 |
| | TAMU/Program Support Grant | 1990 | 2 years | 30,000 | 60,000 |
| | Texas Grain Sorghum Producers | 1990 | 2 years | 50,000 | 100,000 |
| | USDA/APHIS | 1991 | 1 year | 13,200 | 13,200 |
| | TAMU/Program Support Grant | 1990 | 3 years | 27,000 | 81,000 |
| | | | | | **665,316** |
| TAM-126 | Texas Center for Energy | 1989 | 1 year | 14,500 | 14,500 |
| | TAMU/Program Support Grant | 1989 | 3 years | 10,000 | 30,000 |
| | Texas Agr. Exp. Station | 1989 | 5 years | 50,000 | 250,000 |
| | TAES/ERA | 1990 | 2 years | 25,000 | 50,000 |
| | HATCH | 1990 | 4 years | 35,000 | 140,000 |
| | Texas Sorghum Producers | 1990 | 1 year | 15,000 | 15,000 |
| TAM-126 | Grain Sorghum Producers | 1991 | 3 years | 10,300 | 30,900 |
| | TAMU/Hatch | 1992 | 5 years | 31,184 | 155,920 |
| | TAES/ERA | 1990 | 2 years | 19,000 | 38,000 |
| | Grain Sorghum Producers | 1992 | 2 years | 20,000 | 40,000 |
| | | | | | **$ 764,320** |
| TAM-131 | USAID/Honduras PL480 | 1990 | 1 year | 111,395 | 111,395 |
| | USAID/Honduras PL480 | 1991 | 1 year | 120,000 | 120,000 |
| | USAID/Honduras PL480 | 1992 | 1 year | 88,704 | 88,704 |
| | Commercial Seed Co. | 1992 | 1 year | 7,000 | 7,000 |
| | EEC/IICA/PRAIG | 1992 | 3 years | 9,260 | 27,780 |
| | | | | | **$ 354,879** |

| University/ Project No. | Buy-In | Year | Life of Buy-In | Annual Amount | Total |
|---|---|---|---|---|---|
| UNL-113 | Rockefeller Foundation | 1988 | 3 years | 8,333 | 25,000 |
| | Ministry of Science (Leave) | 1991 | 1 year | 25,000 | 25,000 |
| | | | | | **$ 50,000** |
| UNL-115 & 118 | Michigan State/Senegal Agric. | 1989 | 3 years | 46,700 | 140,000 |
| | USAID/Dakar | 1992 | 5 years | 70,000 | 350,000 |
| | | | | | **$ 490,000** |
| UNL-116 | Elliott Grant | 1986 | 4 years | 17,250 | 69,000 |
| | USDA/OICD | 1989 | 3 years | 14,667 | 44,000 |
| | Nebraska Sorghum Board | 1990 | 3 years | 24,00 | 72,000 |
| | USAID/OICD | 1990 | 3 years | 43,000 | 129,000 |
| | USAID/OICD | 1990 | 1 year | 4,000 | 4,000 |
| | | | | | **$ 318,000** |
| UNL-123 | USAID/PSTC Grant | 1989 | 3 years | 50,000 | 150,000 |
| | USDA/ARS | 1986 | 5 years | 22,669 | 113,345 |
| | USDA/ARS | 1991 | 5 years | 24,356 | 121,780 |
| | | | | | **$ 385,125** |
| M.E. | INTSORMIL/Egypt/NARP Nebraska/Kansas St. | 1991 | 3 years | 156,727 | $ 470,183 |
| | SADC/ICRISAT/INTSORMIL Training | 1990 | 5 years | 1,280,400 | 6,402,039 |
| | AID/CROSS CRSP Activities | 1990 | 1 year | 100,000 | 100,000 |
| | USAID/Botswana/DAR | 1990 | 1 year | 35,860 | 35,860 |
| | USAID/Khartoum/ARC | 1990 | 1 year | 80,000 | 80,000 |
| | Social Science Research Workshop | 1991 | 1 year | 31,600 | 31,600 |
| | Adaptation of Plants to Soil Stress Workshop | 1992 | 1 year | 25,000 | 25,000 |
| | | | | | **$ 7,144,682** |
| Total Buy-Ins | | | | | **$ 16,125,178** |

# INTSORMIL Sponsored and Co-Sponsored Workshops 1979 - 1993

| | Name | Where | When |
|---|---|---|---|
| 1. | International Short Course in Host Plant Resistance | College Station, Texas | 1979 |
| 2. | INTSORMIL PI Conference | Lincoln, Nebraska | 1/80 |
| 3. | West Africa Farming Systems | West Lafayette, Indiana | 5/80 |
| 4. | Sorghum Disease Short Course for Latin America | Mexico | 3/81 |
| 5. | International Symposium on Sorghum Grain Quality | ICRISAT | 10/81 |
| 6. | International Symposium on Food Quality | Hyderabad, India | 10/81 |
| 7. | Agrimeteorology of Sorghum and Millet in the Semi-Arid Tropics | ICRISAT | 1982 |
| 8. | Latin America Sorghum Quality Short Course | El Batan, Mexico | 4/82 |
| 9. | Sorghum Food Quality Workshop | El Batan, Mexico | 4/82 |
| 10. | Sorghum Downy Mildew Workshop | Corpus Christi, Texas | 6/82 |
| 11. | Plant Pathology | CIMMYT | 6/82 |
| 12. | Striga Workshop | Raleigh, North Carolina | 8/82 |
| 13. | INTSORMIL PI Conference | Scottsdale, Arizona | 1/83 |
| 14. | INTSORMIL-ICRISAT Plant Breeding Workshop | CIMMYT | 4/83 |
| 15. | Hybrid Sorghum Seed Workshop | Wad Medani, Sudan | 11/83 |
| 16. | Stalk and Root Rots | Bellagio, Italy | 11/83 |
| 17. | Sorghum in the '80s | ICRISAT | 1984 |
| 18. | Dominican Republic/Sorghum | Santo Domingo | 1984 |
| 19. | Sorghum Production Systems in Latin America | CIMMYT | 1984 |
| 20. | INTSORMIL PI Conference | Scottsdale, Arizona | 1/84 |
| 21. | Primer Seminario National Sobre Produccion y Utilizacion del Sorgo | Santo Domingo, Dominican Republic | 2/84 |
| 22. | Evaluating Sorghum for Al Toxicity in Tropical Soils of Latin America | Cali, Colombia | 4/84 |
| 23. | First Consultative and Review on Sorghum Research in the Philippines | Los Banos, Philippines | 6/84 |
| 24. | INTSORMIL Graduate Student Workshop and Tour | College Station, Texas | 6/84 |
| 25. | International Sorghum Entomology Workshop | College Station, Texas | 7/84 |
| 26. | INTSORMIL PI Conference | Lubbock, Texas | 2/85 |
| 27. | Niger Prime Site Workshop | Niamey, Niger | 10/85 |
| 28. | Sorghum Seed Production Workshop | CIMMYT | 10/85 |
| 29. | International Millet Conference | ICRISAT | 4/86 |
| 30. | Maicillos Criollos and Other Sorghum in Middle America Workshop | Tegucigalpa, Honduras | 12/87 |
| 31. | INTSORMIL PI Conference | Kansas City, Missouri | 1/87 |
| 32. | 2nd Global Conference on Sorghum/Millet Diseases | Harare, Zimbabwe | 3/88 |
| 33. | 6th Annual CLAIS Meeting | San Salvador, El Salvador | 12/88 |
| 34. | International INTSORMIL Research Conference | Scottsdale, Arizona | 1/89 |
| 35. | INTSORMIL Graduate Student Workshop and Tour | College Station, Texas | 7/89 |
| 36. | ARC/INTSORMIL Sorghum/Millet Workshop | Wad Medani, Sudan | 11/89 |
| 37. | Workshop on Sorghum Nutritional Grain Quality | West Lafayette, Indiana | 2/90 |
| 38. | Sorghum for the Future Workshop | Cali, Colombia | 1/91 |
| 39. | INTSORMIL PI Conference | Corpus Christi, Texas | 7/91 |
| 40. | Social Science Research and the CRSPs | Lexington, KY | 6/92 |
| 41. | Workshop on Adaptation of Plants to Soil Stresses | Lincoln, NE | 8/93 |

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